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Rev. B

Extravehicular Mobility Unit Systems Training Workbook

EMU SYS 21002

Mission Operations Directorate
EVA, Robotics, & Crew Systems Operations Division
EVA and Crew Systems Operations Branch
EVA Systems Group

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**Extravehicular Mobility Unit
Systems Training Workbook**

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LIST OF EFFECTIVE PAGES

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Technical Support

Subject Matter Expert

Chris Stewart

Foreword

This training manual is intended for self-study by Space Shuttle and International Space Station crewmembers on the subject of the Extravehicular Mobility Unit (EMU). This workbook is prepared by the EVA Systems Group; EVA and Crew Systems Operations Branch; EVA, Robotics, & Crew Systems Operations Division; Mission Operations Directorate (MOD); Lyndon B. Johnson Space Center (JSC).

This training material is part of a series of lectures, handouts, and instructional workbooks used for training purposes only. It should not be used as a source of operational data. This manual should be studied before attending any classroom session covering this material or before taking any lesson for which this is a prerequisite. The EVA operations lesson sequence flow chart shows where this lesson fits in the series, the prerequisites for each lesson, and the optimum presentation order. The lesson sequence charts are located in the Crew Training Catalog.

A lesson critique sheet appears at the end of the book. You should return this with your comments to the author. Any additional questions or comments on this training manual should be directed to the author:

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Section 1
Extravehicular Mobility Unit

The Extravehicular Mobility Unit (EMU), shown in Figure 1-1, is an independent anthropomorphic system that provides environmental protection, mobility, life support, and communications for the crewmember to perform Extravehicular Activity (EVA) in Earth orbit. An EVA is defined, for EMU design considerations, as any time the EMU external environmental pressure is below 4.0 psia.

The Space Shuttle Systems Handbook (SSSH) Drawing 21.10 is an integrated systems schematic of the EMU. You should obtain a copy of this drawing and refer to it while reading this workbook.

The EMU is designed to accommodate an EVA mission with the following characteristics:

a. Total duration of 7 hours maximum, including 15 minutes for egress, 6 hours for useful EVA tasks, 15 minutes for ingress, and 30 minutes of reserves.

b. An average metabolic rate of 1000 Btu/hr for 7 hours.

c. A peak metabolic rate not exceeding 1600 Btu/hr in any given EVA hour and not exceeding 2000 Btu/hr for a period of 15 minutes.

d. A minimum metabolic rate not less than 400 Btu/hr for a period of 30 minutes.

The EMU is an integrated assembly, primarily made up of the Space Suit Assembly (SSA), Life Support Subsystem (LSS), and numerous items of associated support and ancillary equipment.

1.1 Space Suit Assembly

The space suit assembly consists of the following:

a. Hard Upper Torso (HUT)/arms - The portion of the actual pressure suit above the waist, excluding the gloves and helmet; also referred to as a “Short EMU” (SEMU).

b. Lower Torso Assembly (LTA) - The portion of the pressure suit below the waist, including the boots.

c. Extravehicular (EV) gloves - The anthropomorphic hand protection of the pressure suit.

d. Helmet/Extravehicular Visor Assembly (EVVA) - The portion of the pressure suit providing pressurization for the head as well as impact, glare, and thermal protection.

e. Liquid Cooling and Ventilation Garment (LCVG) - A garment worn under the pressure suit with sewn-in tubes to provide circulation of cooling water and for pickup of vent flow at the extremities.

f. Operational Bioinstrumentation System (OBS; Biomed) - Instrumentation used to monitor the crewmember's heart rate during EVA.

g. Communications Carrier Assembly (CCA; comm cap) - A cap worn under the helmet to position and hold the crewmember's earphones and microphones.

h. In-suit Drink Bag (IDB) - A flexible container/dispenser used to provide drinking water to the crewmember while inside the space suit. Disposable In-Suit Drink Bags (DIDBs) will be used for space-station-based EVAs.

i. Urine Collection Device (UCD) - A device for collecting a male crewmember's urine.

j. Maximum Absorbency Garment (MAG) - A device to absorb crewmember urine.

1.2 Life Support System

The life support system consists of the following:

a. Primary Life Support Subsystem (PLSS) - The backpack assembly that normally provides the EVA crewmember with oxygen for breathing, ventilation, and pressurization; it also provides water for cooling.

b. Secondary Oxygen Pack (SOP) - An assembly that provides oxygen for breathing, ventilation, pressurization, and cooling in the event of a malfunction of the primary O_2 tanks or a suit leak. The SOP is contained within the EMU backpack (attached to the PLSS). Although the SOP is not a part of the PLSS, it is discussed immediately after the primary O_2 system because both oxygen systems have a common point of interface in the ventilation loop.

c. Contaminant Control Cartridge (CCC) - A crew-replaceable module used in the PLSS to remove CO_2, odors, particulates, and other contaminants from the ventilation circuit.

d. Battery - A removable, rechargeable, internal silver-zinc battery that supplies all power to the EMU.

e. Space-to-Space EMU Radio (SSER) - This system, which includes transceivers and an antenna, provides voice and data communication for the EMU.

f. Real-Time Data System (RTDS) - System that acquires EMU caution and warning data and routes serial data to the orbiter for downlink to ground-based equipment.

g. Caution and Warning System (CWS) - System that consists of instrumentation and a microprocessor to obtain, process, monitor, and visually display information for use by the EVA crewmember in the operation and management of the EMU.

h. Display and Control Module (DCM) - The crewmember interface with the PLSS. Mounted on the front of the upper torso, the module contains displays and controls associated with the operation of the EMU.

Figure 1-1. Extravehicular mobility unit

Section 2
Enhanced Space Suit Assembly

The enhanced SSA is the pressure vessel that encloses the crewmember's torso, limbs, and head. It has greater sizing flexibility than the baseline SSA it replaced. This is achieved by using sizing rings in the arm, thigh, and leg and by using cam adjustments on the arm and leg segments. The arm segments, leg segments, and sizing rings can be added or removed easily on orbit. The EMU is certified for zero or one ring at the appropriate connection points; therefore, rings cannot be stacked.

The SSA provides the following functions:

a. Suit pressure retention

b. Crewmember mobility

c. Crewmember insulation and liquid cooling distribution

d. O_2 ventilation gas circulation

e. Downlink of crewmember's Electrocardiogram (ECG) and suit data via EMU radio

f. Crewmember interface with EMU radio

g. Crewmember in-suit drinking water

h. Urine containment

i. Protection from radiation, micrometeoroids, and orbital debris

The SSA includes the following components:

a. Hard upper torso/arm assembly (SEMU)

b. Lower torso assembly

c. EV gloves

d. Helmet/extravehicular visor assembly

e. Liquid cooling and ventilation garment

f. Operational bioinstrumentation system

g. Communications carrier assembly

h. In-suit drink bag

i. Urine collection device

j. Maximum absorbency garment

The liquid cooling and ventilation garment, operational bioinstrumentation system, communications carrier assembly, in-suit drink bag, urine collection device, and maximum absorbency garment are included in the SSA, but these components are not part of the pressure garment.

SSA pressure requirements are shown in Table 2-1. Table 2-2 shows the number of sizes available for each SSA pressure garment component.

Table 2-1. SSA pressure requirements

Pressure type	Pressure (psid)
PRESS/EVA operating pressure	4.3 ± 0.1
IV operating pressure	0.9 ± 0.5
Maximum operating pressure	5.3
Structural pressure	6.6
Proof pressure	8.0
Burst pressure	10.6

Table 2-2. SSA/pressure garment component sizes

Component	Number of sizes
Helmet	1
Planar HUT	3 (M, L; XL scheduled for 2000)
Arm assembly	
Scye bearing	1
Upper arm	1
Arm bearing	1
Arm sizing ring	1
Arm adjustment cam	1
Lower arm	8
Wrist adjustment cam	1
Wristbearing/disconnect	1
Glove	
Standard	9
Custom	Unlimited
Lower torso assembly	
Body seal closure	1
Waist assembly	5
Waist bearing	1
Thigh/brief assembly	2
Thigh sizing ring	1
Thigh adjustment cam	1
Leg segment	5
Leg adjustment cam	1
Boot sizing ring	3
Boot disconnect	1
Boot assembly	2
Boot sizing insert	6
Thermal slippers	2

2.1 Hard Upper Torso/Arm Assembly

The HUT provides pressure containment for the upper torso. It also is a central component, with the EMU mechanical, electrical, and fluid interfaces branching out from it. The new design is called the planar HUT and has replaced the older pivoted HUT. The planar HUT is currently available in two sizes, medium and large. An extra large size is planned. It is an On-Orbit Replaceable Unit (ORU), and can separate from the PLSS and DCM. This permits servicing or replacement of these components in the event of failure.

The HUT includes the following components (Figures 2-1 and 2-2):

a. Fiberglass shell with non-encapsulated tube ducts

b. Assorted mounting brackets

c. Waterline and vent tube assembly

d. Multiple water connector (with locking mechanism)

e. EMU electrical harness

f. Fixed arm openings with forward cant

g. Body seal closure that mates to the LTA

h. Helmet disconnect ring (with locking mechanism)

i. One-piece HUT Thermal Micrometeoroid Garment (TMG)

The Hard Torso Shell (HTS) is the structural backbone of the HUT. The planar HTS is made from cloth layers of epoxy resin fiberglass and contains arm sockets, water tubes, and O_2 ducts. The ducts and tubes are protected by shields that are Velcroed to the fiberglass. In the pivoted HUT, these fluid lines were integral with the fiberglass HTS wall. This enhancement was added to simplify ground servicing of the fluid lines. PLSS and DCM interface pads provide pass-through passages for water tubes and O_2 ducts. These access points allow water and O_2 from the PLSS to flow to the DCM, LCVG, and HUT. The PLSS is attached to the HUT at three points: two studs and a PLSS/HUT interface. The DCM also has three attachment points: the DCM pad and the upper and lower DCM mounting bosses (Figures 2-1 and 2-2). A waterline and vent tube assembly is secured to a connector block on the inside back wall of the HUT (Figure 2-3). This assembly is made up of two flexible waterlines that straddle the O_2 return duct and terminate in a Multiple Water Connector (MWC). The connector contains a locking mechanism that mates with an LCVG half and thus allows the flow of cooling water in and out of the LCVG and provides a passage for vent gas return to the PLSS.

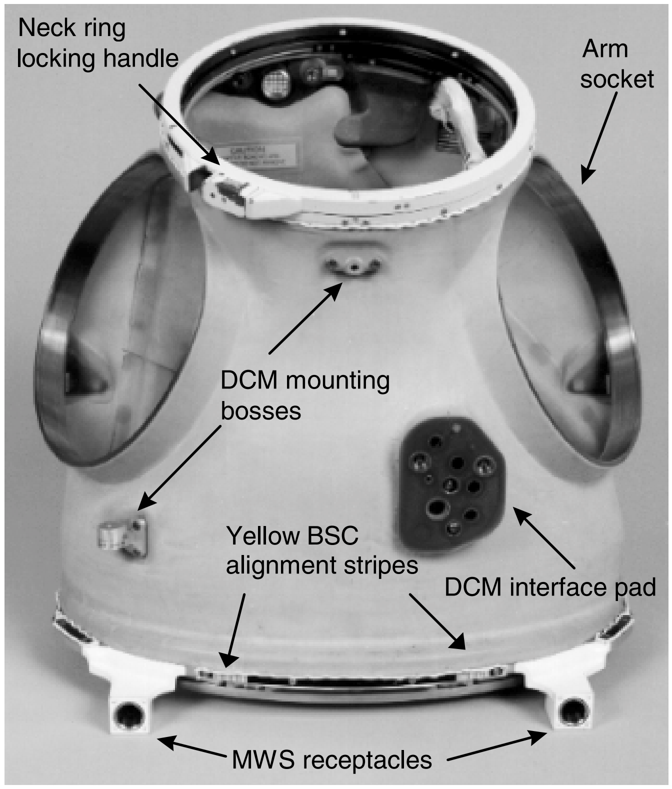

Figure 2-1. Planar HUT - Front view, without TMG

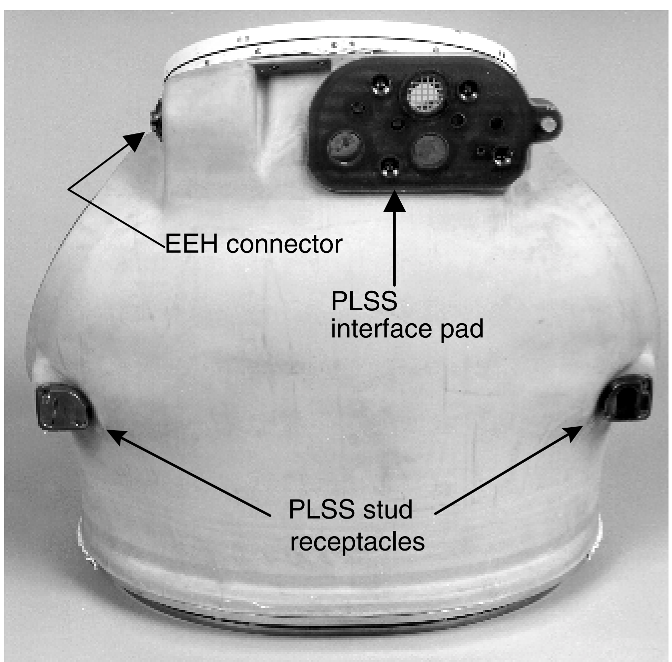

Figure 2-2. Planar HUT - Back view, without TMG

In the HUT, a D-shaped hole (located near the left shoulder) is provided for the EMU Electrical Harness (EEH). The EEH is routed over the left shoulder to the front center of the HUT and terminates in two similar disconnects (Figure 2-3). One disconnect interfaces with the CCA, and another connects to the biomed signal conditioner in the LCVG. The EEH interfaces with the SSER to provide communications and downlinked ECG data.

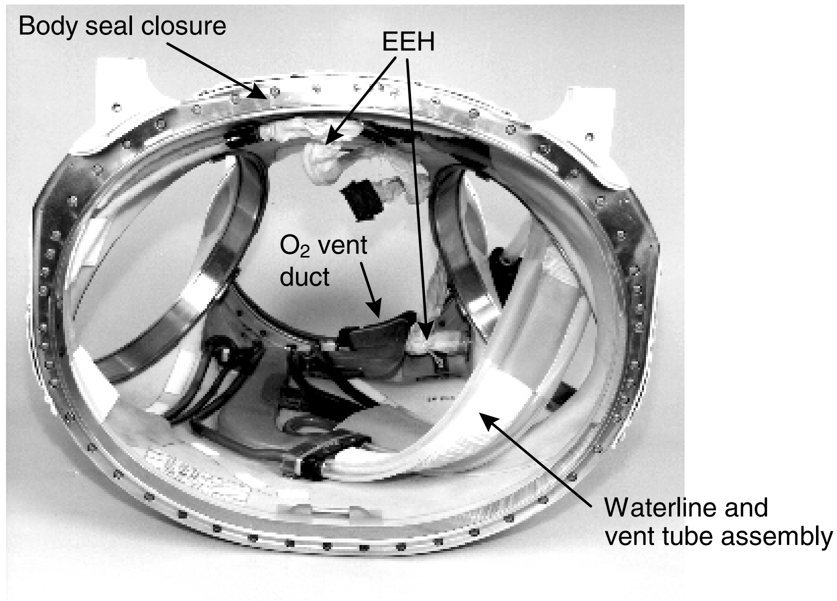

Figure 2-3. Planar HUT - Bottom view, without TMG

The helmet is attached to the HUT with a quick disconnect neck ring. The ring has three positions: open, engage, and locked. These positions are controlled by a neck ring locking handle (Figure 2-4). This handle moves a locking ring cam that actuates eight latch pins (dogs). The dogs extend out of the ring in the locked and engage positions; they are forced to retract in the open position. The spring-loaded handle returns to the engage position when released from the open position. This safety feature ensures that if a helmet is properly installed, it is positively captured by the latch dogs and cannot inadvertently disconnect. A conscious effort, requiring three motions in different directions, must be initiated to disengage the helmet from the neck ring. The three motions consist of depressing a lock button, pulling out the actuator tab, and sliding the actuator toward the left of the suit. The neck ring also contains an opening for the oxygen vent duct. O_2 ventilation flow enters the SSA through this vent duct (located on the rear of the neck ring). The vent duct opening aligns with an opening on the helmet half of the neck ring so that O_2 can flow through the neck ring to a helmet vent pad, which directs the flow over the top of the crewmember's head.

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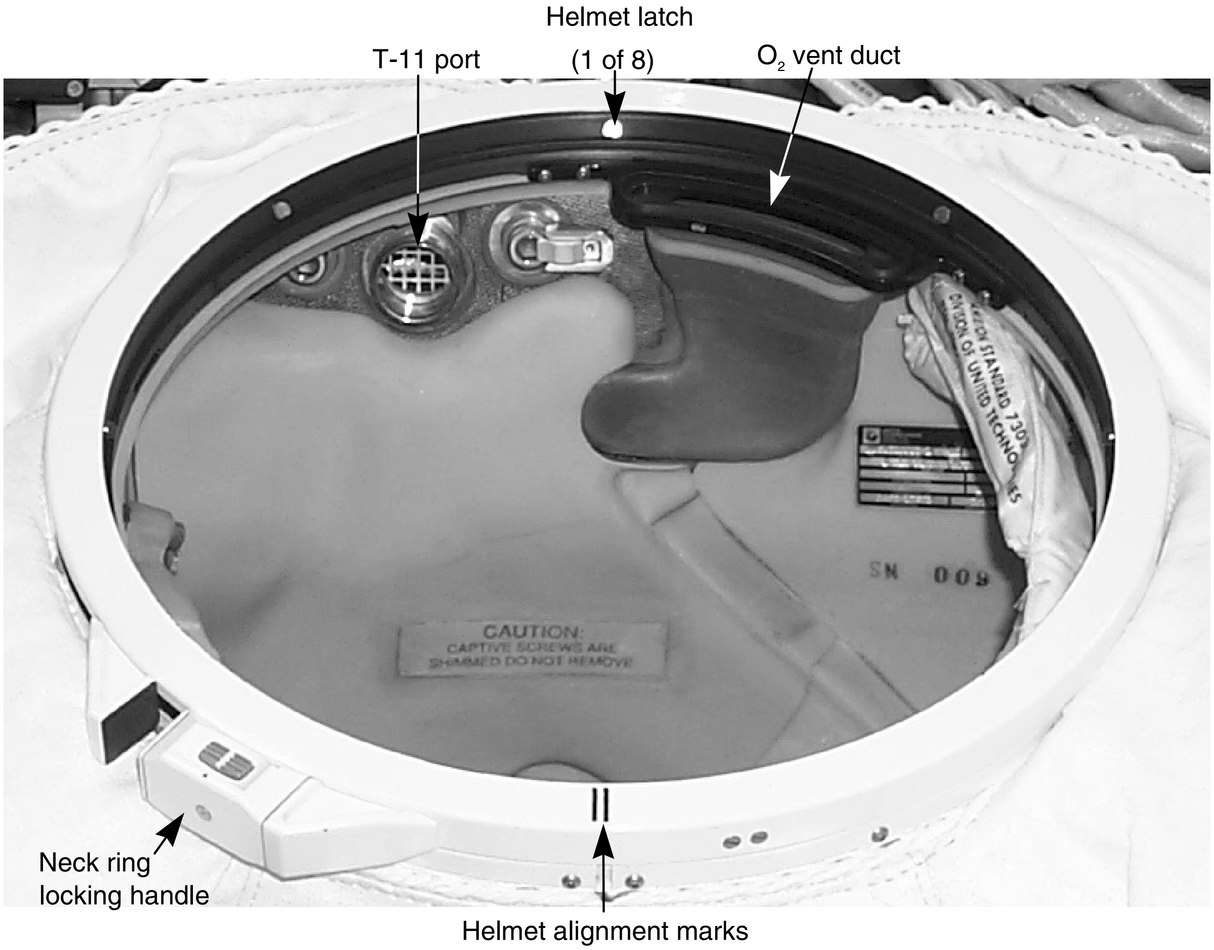

Figure 2-4. HUT neck ring

The HUT contains also the passive half of the Body Seal Closure (BSC) (Figure 2-3). This quick disconnect ring attaches the LTA to the HUT. The HUT half of the BSC has alignment stripes and a circular opening that accepts a pin for aligning the LTA and HUT during donning. The planar HUT uses one size, a standard 16-inch BSC, to maximize interchangeability. This allows all sizes of planar HUTs to be used with the same size LTA. The HUT half also has two metal receptacles for attachment of the Mini-Workstation (MWS). The MWS (discussed in Section 4.5) contains bayonet fittings that attach to these receptacles.

A one-piece TMG covers the exterior of the HUT in areas not covered by the PLSS and DCM. The TMG, which is used throughout the entire EMU, consists of an outer solar radiation-reflecting layer of white ortho fabric, five insulating layers of aluminized reinforced Mylar film, and an inner lining of neoprene-coated nylon ripstop. Exposed surfaces of the helmet disconnect and BSC are coated with thermal insulating paint.

The upper arm interface with the HUT is a rotating scye bearing (Figure 2-5). The planar HUT arm openings contain stainless steel scye bearing retainer rings. The planar HUT design eliminates the bellows assembly used in the pivoted HUT. This design change results in a

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more durable interface but eliminates the “jumping jack” motion at the shoulder. To compensate for this motion loss, the planar HUT has arm openings that are canted forward. This design gives crewmembers enhanced work envelope mobility.

The right and left enhanced arm assemblies are flexible, anthropomorphic pressure vessels that encompass the arms (Figure 2-5). Each enhanced arm assembly includes the following components:

a. Upper arm assembly

b. Lower arm assembly (Figure 2-6)

c. Arm sizing ring

d. Wrist disconnect ring (with locking mechanism)

e. Urethane pressure bladders, cloth restraint systems, and TMGs for the upper and lower arm assemblies

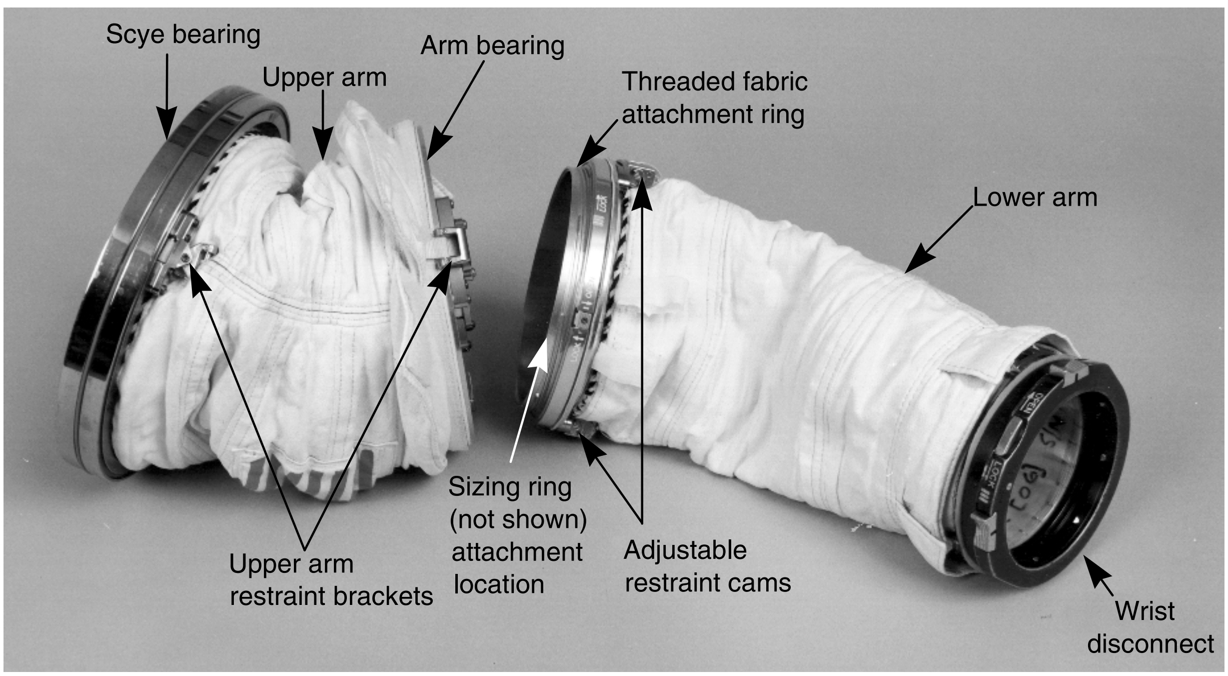

Figure 2-5. Enhanced arm assembly

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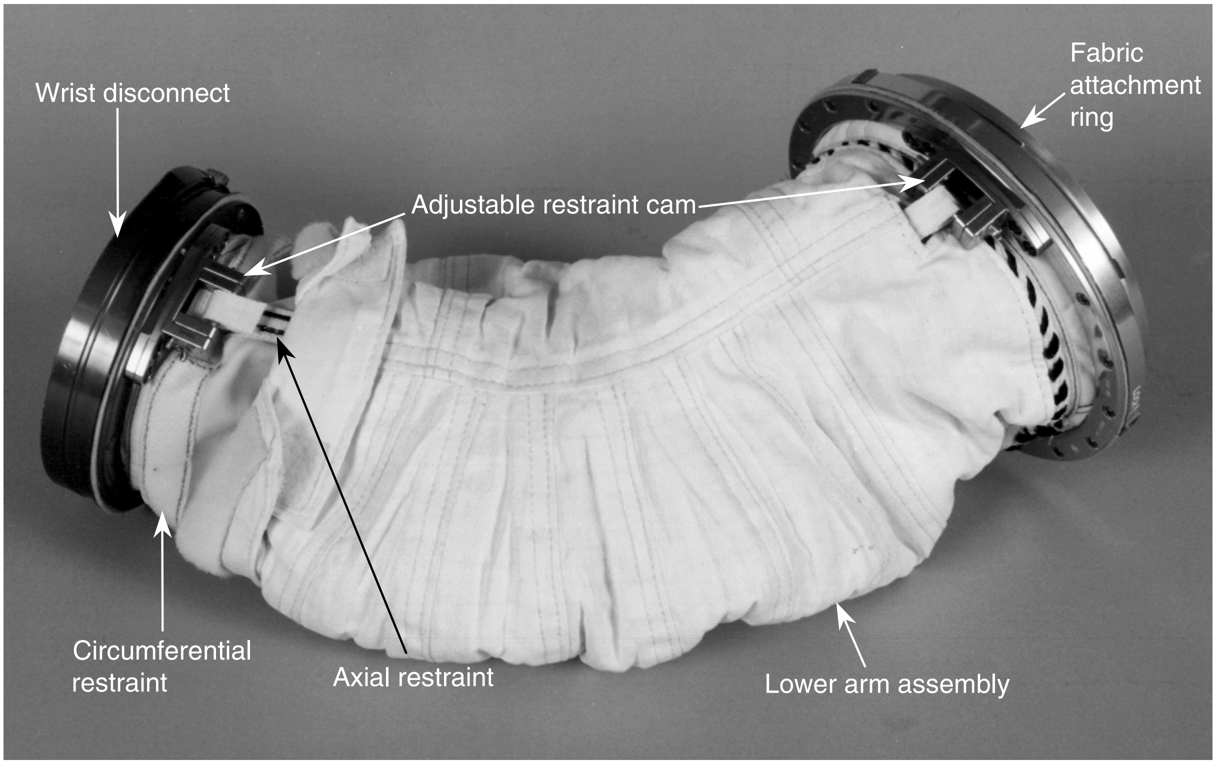


Figure 2-6. Lower arm assembly

The upper arm assembly is available in one size, and the lower arm assembly is available in eight sizes. Each upper arm has a rotating dual seal scye bearing to provide shoulder mobility. A second bearing between the upper and lower arm assemblies provides forearm mobility. A disconnect is provided in one size at the wrist for attaching the glove. A 0.5-inch-long sizing ring may be added between the upper and lower arm segments to provide sizing adjustments (Figures 2-7 and 2-8).

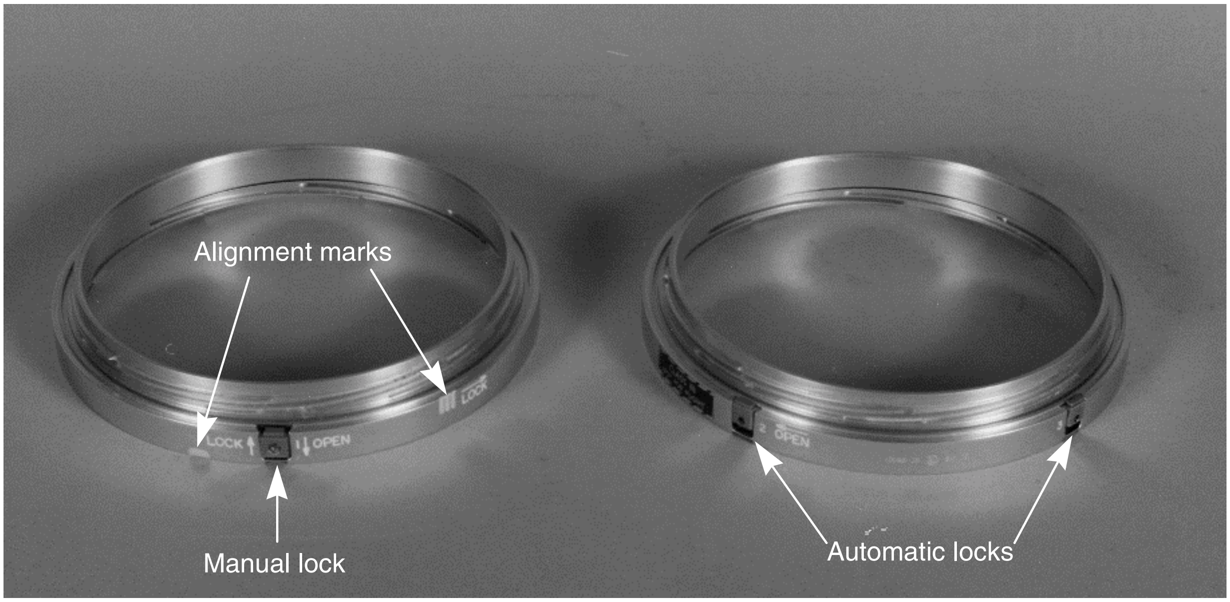


Figure 2-7. Two arm sizing rings

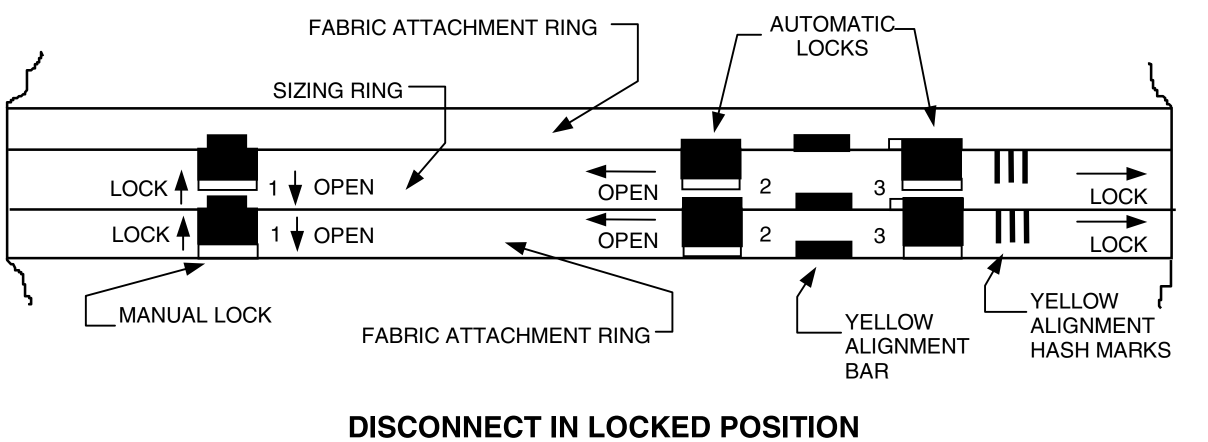


Figure 2-8. Sizing ring drawing

Sizing adjustments also can be made with adjustable arm cam brackets (Figures 2-9, 2-10, and 2-11). One bracket is located at each end of the lower arm; each bracket allows an adjustment of 0.25 inch.

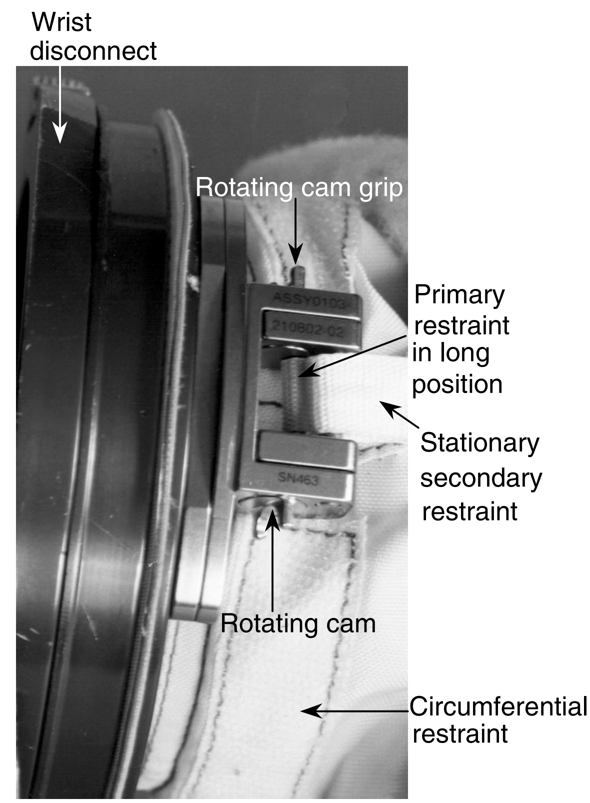


Figure 2-9. Arm cam in long position

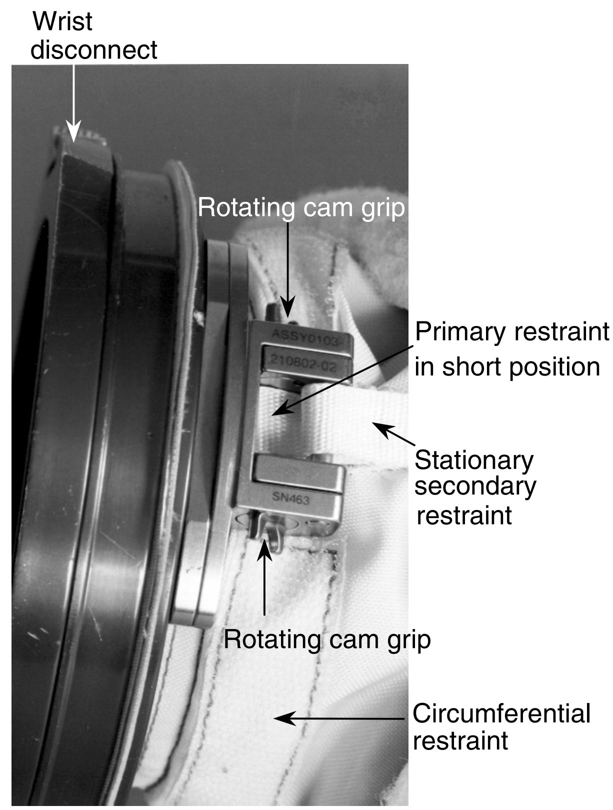
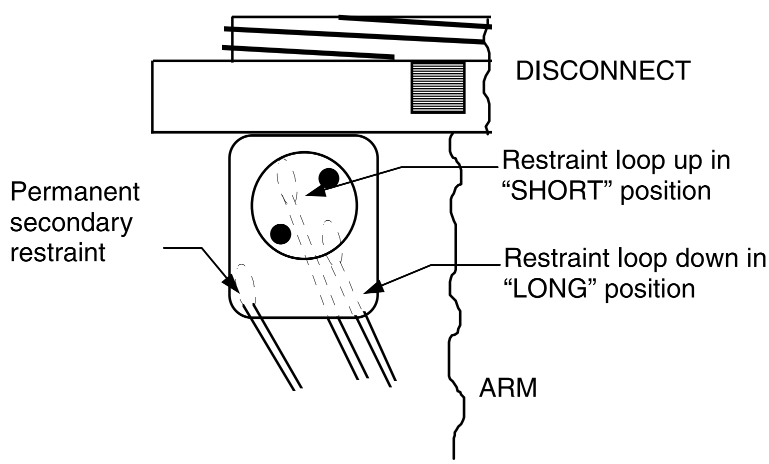


Figure 2-10. Arm cam in short position



ARM CAM ADJUSTMENT (0.25 inch per cam)

Figure 2-11. Arm cam drawing

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Both upper and lower arm assemblies contain a heat-sealed, urethane-coated nylon bladder to maintain pressure integrity. Fully redundant primary and secondary restraint line webbings carry axial loads between the arm and scye bearings. Each restraint line is separately attached to an individual bracket at the scye and arm bearings. Polyester fabric that surrounds the bladder restrains circumferential pressure loads. The bladder and restraint fabric are flange mounted to each bearing and to the disconnect.

A separate TMG is provided for the upper and lower arm assemblies to provide thermal and micrometeoroid protection.

Wrist disconnects provide the interface for the glove assemblies with the lower arm assemblies (Figure 2-12). As with the neck ring, each wrist disconnect contains eight latch dogs to engage and lock the glove to the suit arm. These latch dogs have open, engage, and locked positions. Three locks on the arm side of the disconnect prevent inadvertent disengagement of a glove. The disconnect is marked to show the OPEN and LOCK positions as well as the direction of rotation. The engage position is indicated by yellow alignment marks. Releasing the wrist disconnect consists of depressing the center lock, sliding the outboard locks, and rotating the locking ring to disengage the glove. The disconnect locks in the OPEN position for LCVG donning. After wrist disconnect engagement, locking can be performed by simply rotating the locking ring (lock actuation is not required).

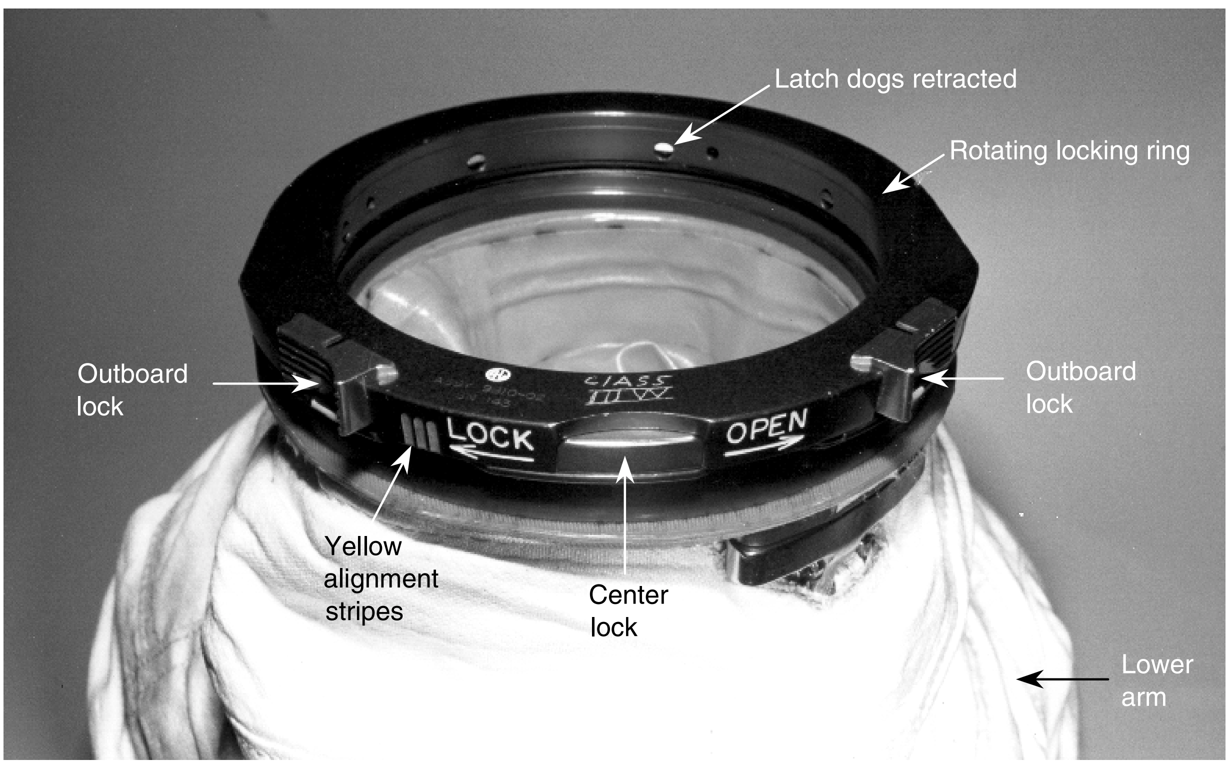

Figure 2-12. Wrist disconnect

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2.2 Enhanced Lower Torso Assembly

The enhanced LTA, which encompasses the waist, legs, and feet, includes the following components (Figure 2-13):

a. Waist-brief assembly - This assembly includes the BSC with locking mechanism, waist assembly, rotating dual seal waist bearing, and brief assembly

b. Thigh sizing ring

c. Leg assembly

d. Leg sizing rings

e. Boot assembly

f. Urethane pressure bladders, cloth restraint systems, and TMGs for the waist, brief, leg, and boot assemblies

g. Leg restraint adjustment brackets (each adjusts 0.5 inch)

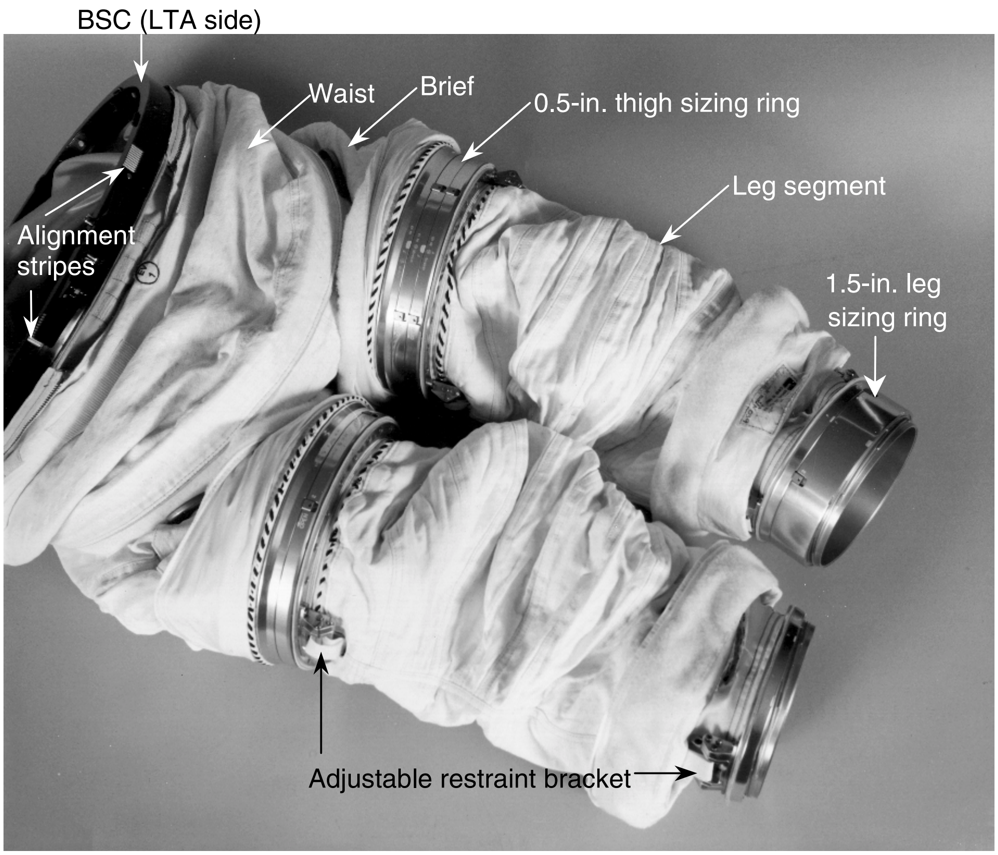

Figure 2-13. Enhanced LTA without boots

Some improvements that the enhanced LTA incorporates include quicker on-orbit resizing due to the sizing rings and adjustment brackets.

The waist-brief assembly is the transition from the HUT to the trouser portion of the LTA. It interfaces with the HUT at the BSC (waist ring) and with either the thigh sizing ring or the leg assembly just above the crewmember's knee. The waist bearing is located at the lower waist to permit rotation of the trunk. The LTA half of the BSC contains the active latching mechanism of the BSC. This disconnect is similar to the helmet neck ring disconnect, but there are differences, which include the following:

a. The waist ring contains 12 latch dogs instead of 8 as on the helmet neck ring.

b. The waist ring contains a doffing assist lever to assist when moving the locking handle from the engage to the open position (Figure 2-14).

c. The locking handle is not spring loaded and the handle can be left in the open position to prevent the crewmember from snagging the LCVG on the latch dogs while donning or doffing the LTA.

d. The LTA half of the waist ring has an alignment pin, in addition to alignment stripes, to mate with a recess in the HUT half for LTA and HUT alignment during donning.

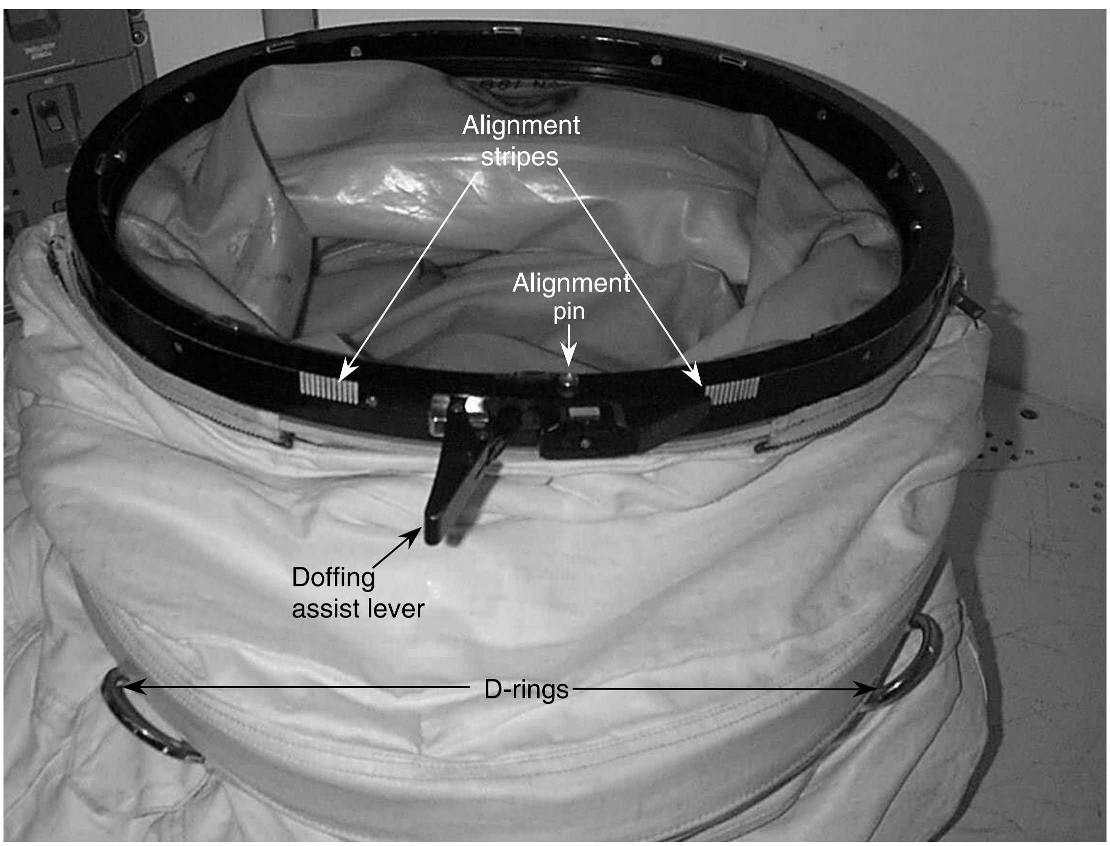

Figure 2-14. BSC (LTA half)

A pair of LTA donning handles (Figure 4-19) is provided to aid in the mating of the HUT and the LTA halves of the waist ring. A metal bracket is mounted on both the left and right sides of the LTA half of the waist ring to interface with these donning handles. The length of the waist-brief assembly can be adjusted on the ground during processing by a total of 2 inches. An on-orbit adjustable waist is planned.

The thigh-sizing ring, when added between the waist-brief assembly and the leg assembly, increases the length of the LTA by 0.5 inch (Figure 2-15).

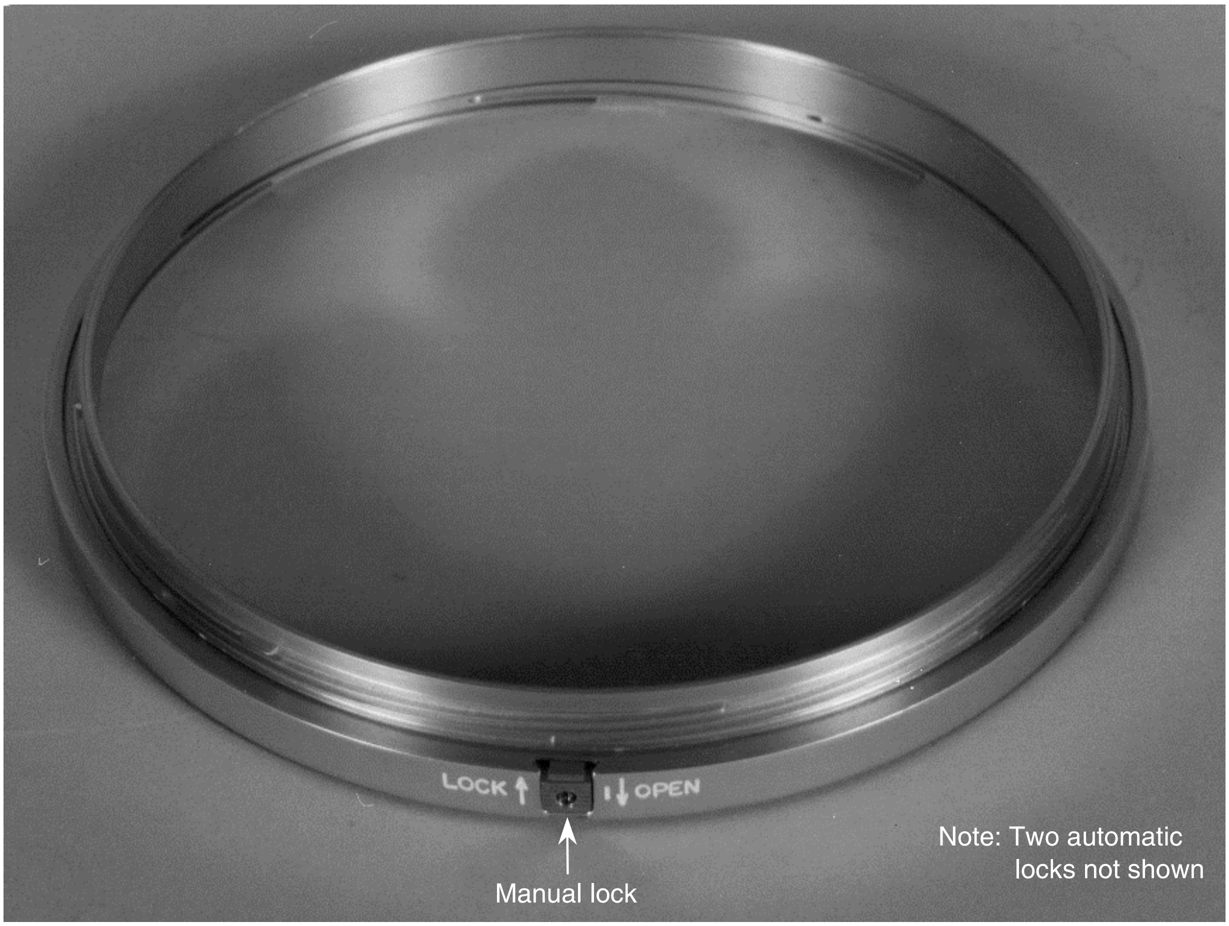

Figure 2-15. Thigh sizing ring

The leg assembly consists of upper and lower attachment rings, a knee assembly, on-orbit adjustable leg restraint brackets, and a TMG (Figure 2-16). The length of the leg assembly can be changed on orbit by up to 1.0 inch by adjusting each of the leg brackets by 1/2 inch per cam (Figure 2-17). This is done by removing the primary restraint pin, rotating to the other restraint loop position, and replacing the pin (Figures 2-18 to 2-20).

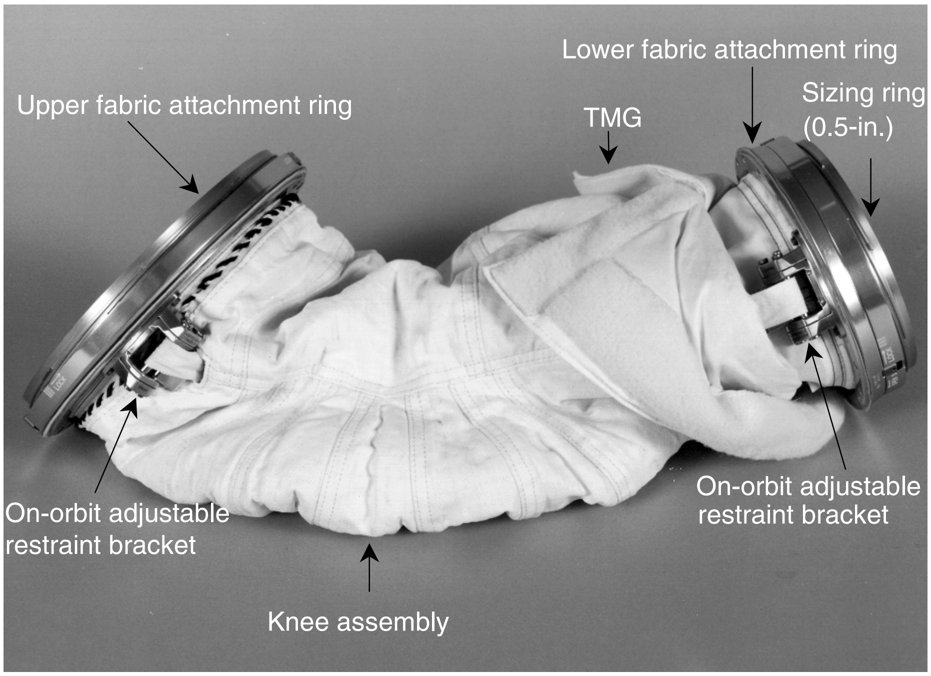

Figure 2-16. Leg assembly

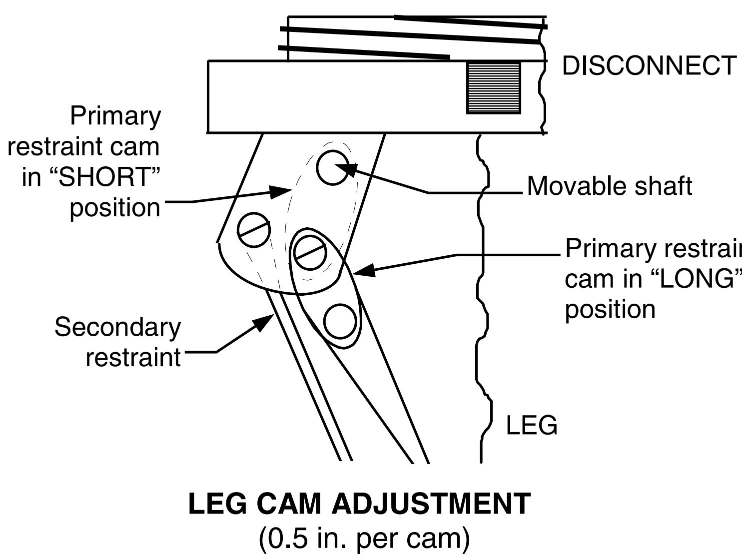

Figure 2-17. Leg cam adjustment drawing

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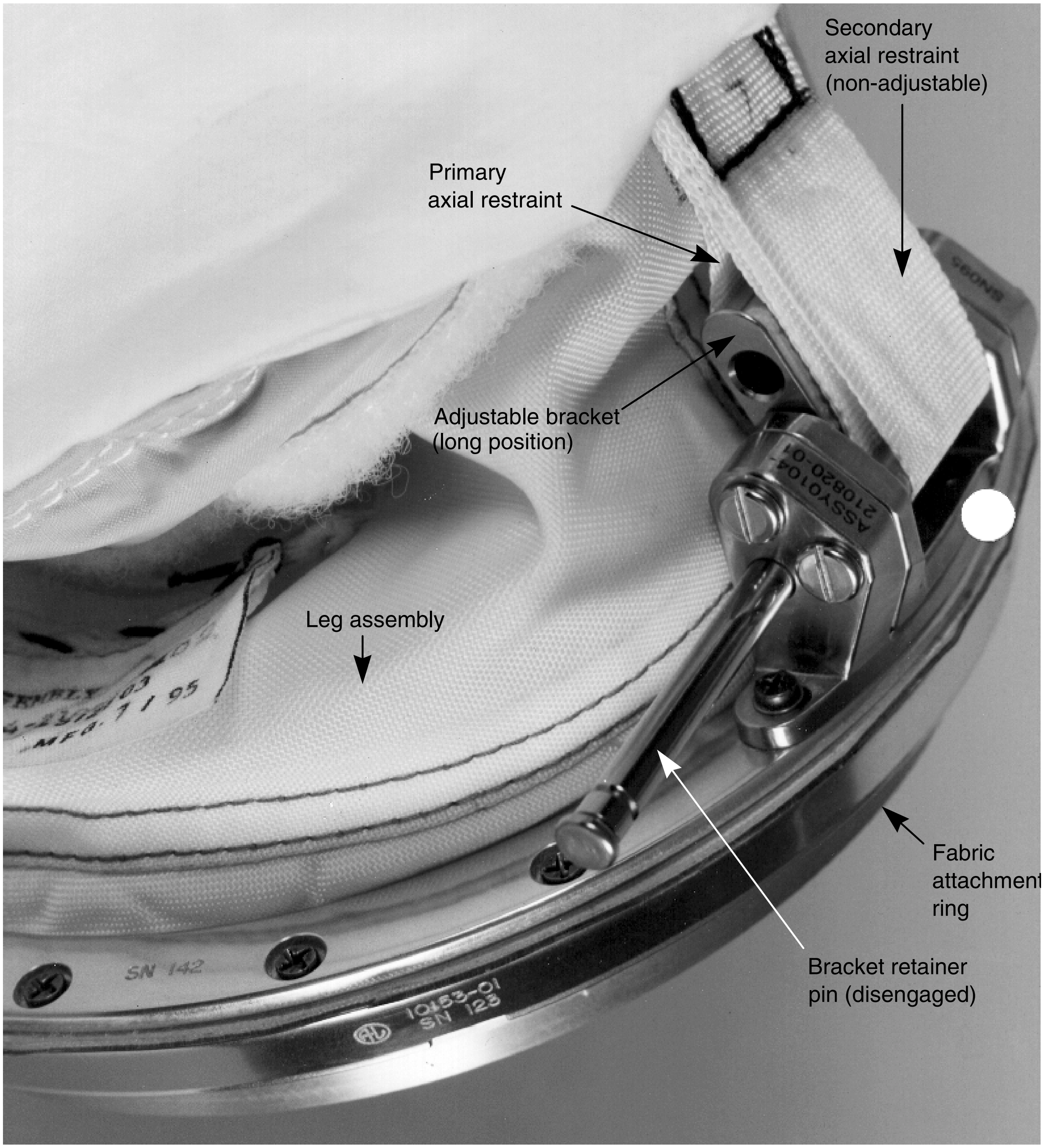


Figure 2-18. Adjustable restraint bracket with pin disengaged

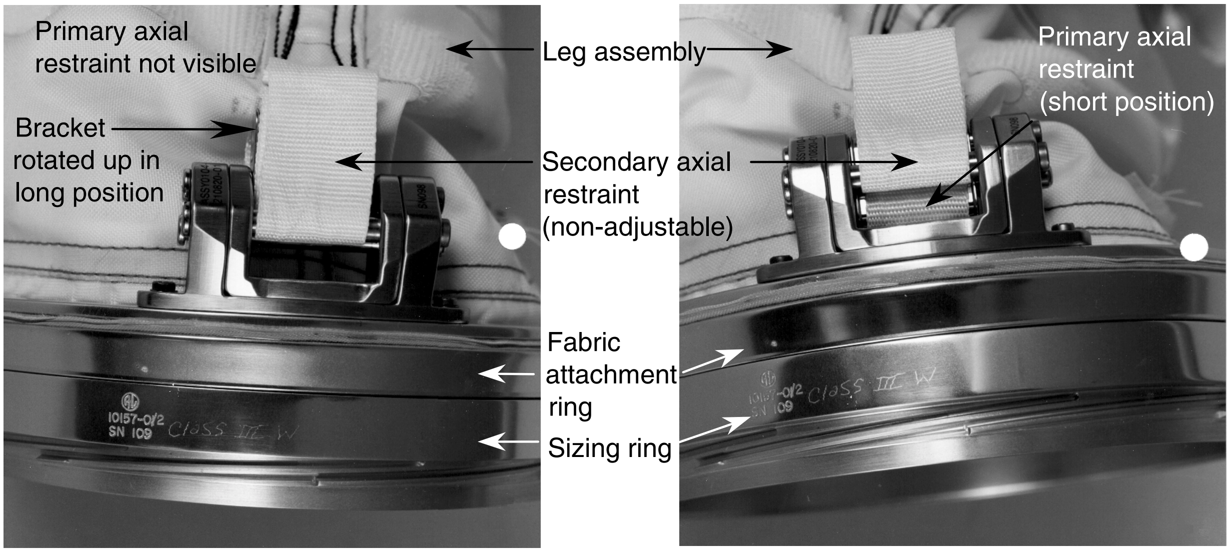


Figure 2-19. Adjustable restraint bracket secured in long position

Figure 2-20. Adjustable restraint bracket secured in short position

The leg sizing rings come in 0.5-, 1.0-, and 1.5-inch lengths (Figure 2-21). These can be screwed onto the lower attachment ring of the leg assembly and the upper attachment point of the boot assembly. The combination of these rings, five sizes of leg assemblies, and the adjustable leg brackets allow for many variations in the length of the LTA. This ensures that the LTA knee convolutes can be lined up properly with the crewmember's knee.

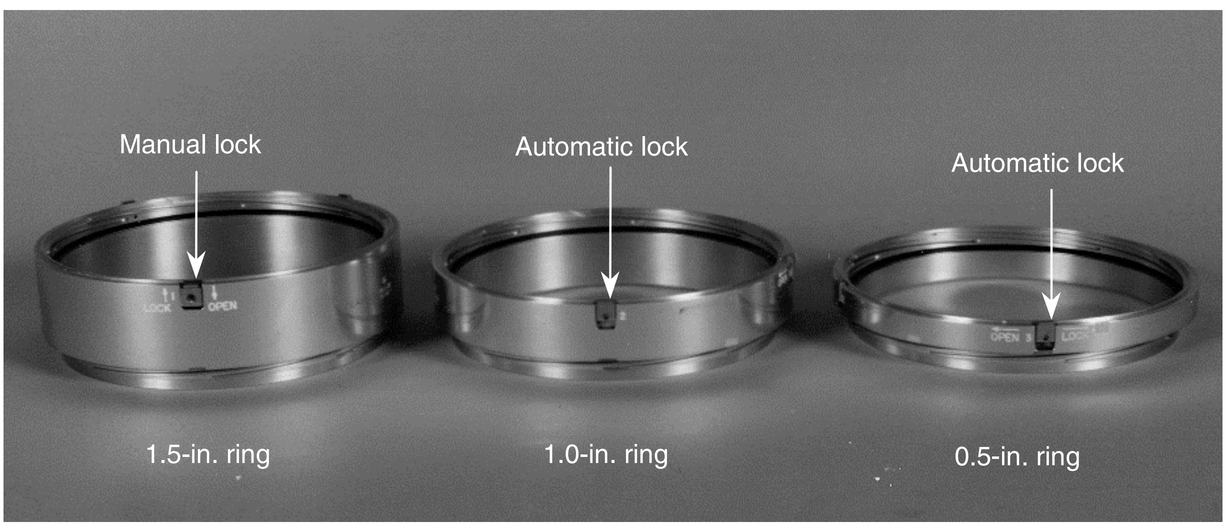


Figure 2-21. Leg sizing rings

The boot assembly encloses the crewmember's feet and completes the LTA by interfacing with the leg assembly and/or leg sizing rings at the boot disconnect (Figure 2-22). The boots contain sole and heel subassemblies that interface with the EVA foot restraints. Boot inserts can be added if necessary to improve boot fit (Figure 2-23).

Figure 2-22. Enhanced boot

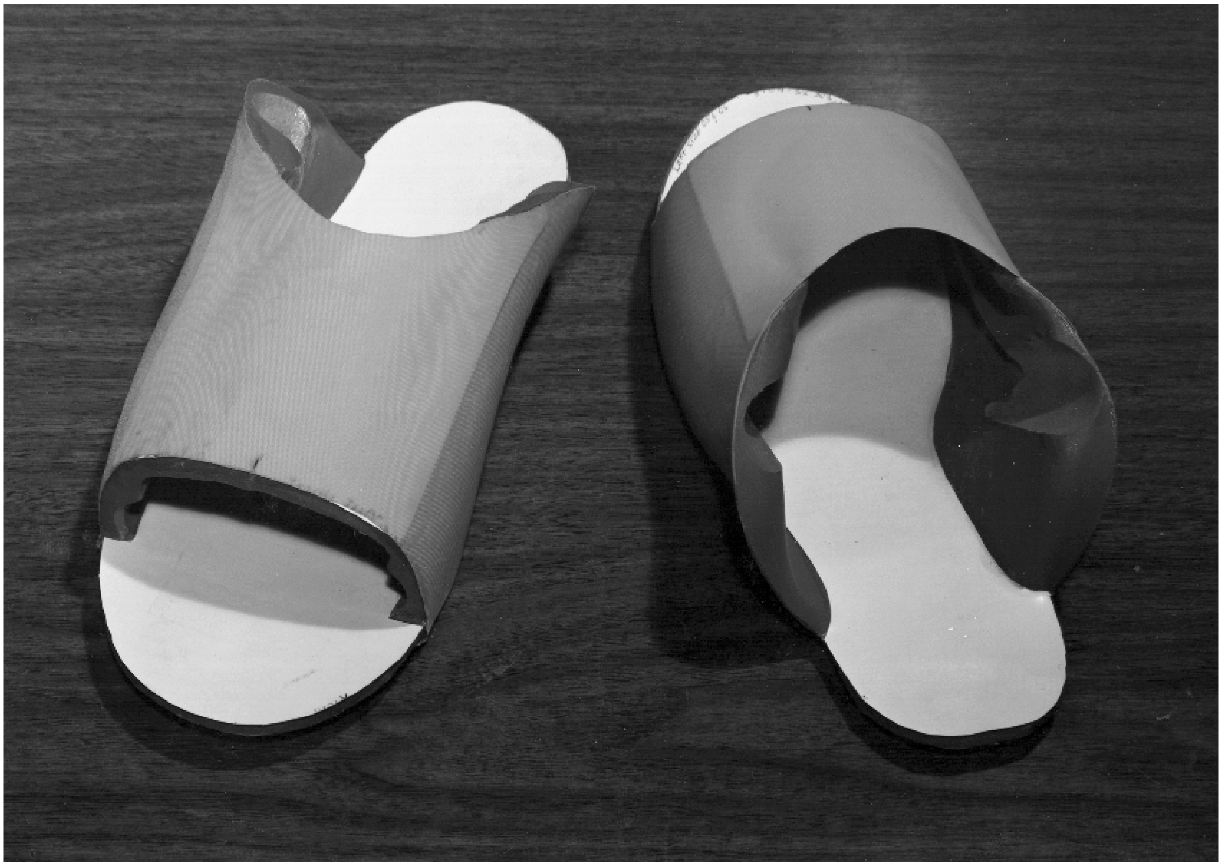
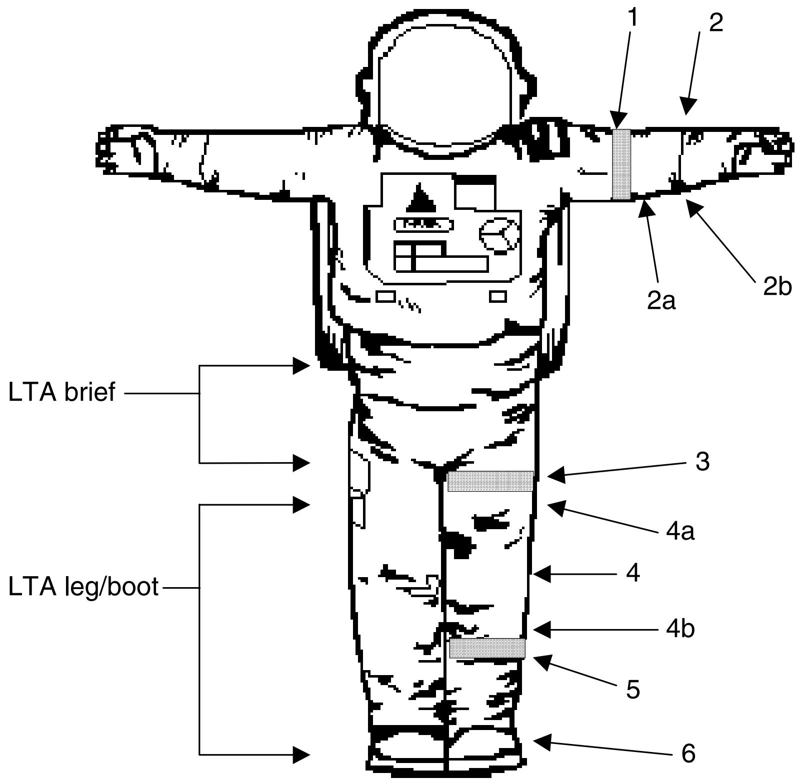


Figure 2-23. Boot inserts

Thermal/micrometeoroid protection is provided by separate TMGs for the waist, brief, leg, and boot assemblies. A small pocket is included on the front of the right thigh for stowage of the EMU scissors (discussed in Section 4.2).

Each LTA element has sizing provisions (refer to Table 2-2 for more details). An overview of enhanced EMU sizing items is shown in Figure 2-24.



Item number	Item name	Length
1	Arm sizing ring	1/2 in.
2a	Adjustable arm restraint cam	Approx. 1/4 in.
2	Arm segment	Sizes 00 to 08, (7 in. to 14 in.)
2b	Adjustable arm restraint cam	Approx. 1/4 in.
3	Thigh sizing ring	1/2 in.
4a	Adjustable leg restraint bracket	1/2 in.
4	Leg segment	Sizes 01 to 05 (13 in. to 22 in.)
4b	Adjustable leg restraint bracket	1/2 in.
5	Leg sizing ring	0.5 in., 1 in., 1.5 in.
6	Boot	Small, large

Figure 2-24. Enhanced EMU nomenclature

Nylon bladder assemblies that are heat-sealed and urethane-coated maintain pressure integrity. The bladder and the Dacron restraint fabric assemblies are flange-mounted to the BSC, to both sides of the waist bearing, and to the leg and boot attachment rings.

The LTA restraint assembly manages circumferential loads on the LTA. This assembly is constructed from a plain weave polyester fabric. Axial loads are managed by the axial restraint webbing that consists of high strength, low elongation spectra webbing in the brief and leg assemblies, and polyester webbing in the boot and waist assemblies. This webbing limits stretching of the article when pressurized. Fully redundant primary and secondary restraint line webbings handle the axial loads. The ends of these webbings are separately attached to brackets at the BSC, waist bearing, and leg and boot attachment rings. This allows the axial loads to be transferred from one side of the BSC to the other through a continuous loop of the axial restraints.

Two D-shaped tether brackets are bolted to the lower half of the waist bearing to provide for attachment of waist tether hooks (Figure 2-14).

2.3 EV Gloves

The EV glove is the active interface between the crewmember and the work being performed. While preserving an effective degree of nude hand mobility and tactility, the glove provides a protective barrier against hazards from both the work environment and the work site. EV glove designs consist of the following subcomponents:

a. Bladder and restraint assembly to maintain pressure and structure

b. Gimbal ring system to achieve wrist mobility

c. Adjustable palm restraint assembly to maintain a conformal palm area

d. TMG assembly to protect from the environment and the work area

e. Wrist bearing/disconnect assembly to achieve wrist mobility and glove removal

f. Wrist tether loop to attach tools and tethers

Two separate EV glove designs are now being used with the EMU, the 4000 series glove and the newer phase VI glove. The subcomponents of these two designs are discussed in detail in the following sections.

2.3.1 4000 Series Glove Assembly

The 4000 series gloves (which evolved from the 1000-3000 series gloves) incorporate a standard nine-size system to provide a comfortable fit for the 5th to 95th percentile of men and women (Figure 2-25). Modified 4000 series gloves can be manufactured for the crewmember if a proper fit cannot be obtained within the standard size spectrum. Specific fit adjustments, within a certain glove size, can be achieved during ground processing by changing the length of individual fingers using a pair of polyester Dacron cords. These cords are trapped in channels formed by the stitch rows that join the front of the restraint finger to the back (Figure 2-26). Finger sizing is accomplished by adjusting these cords in a drawstring fashion. The full range of adjustment is approximately 1/2 inch.

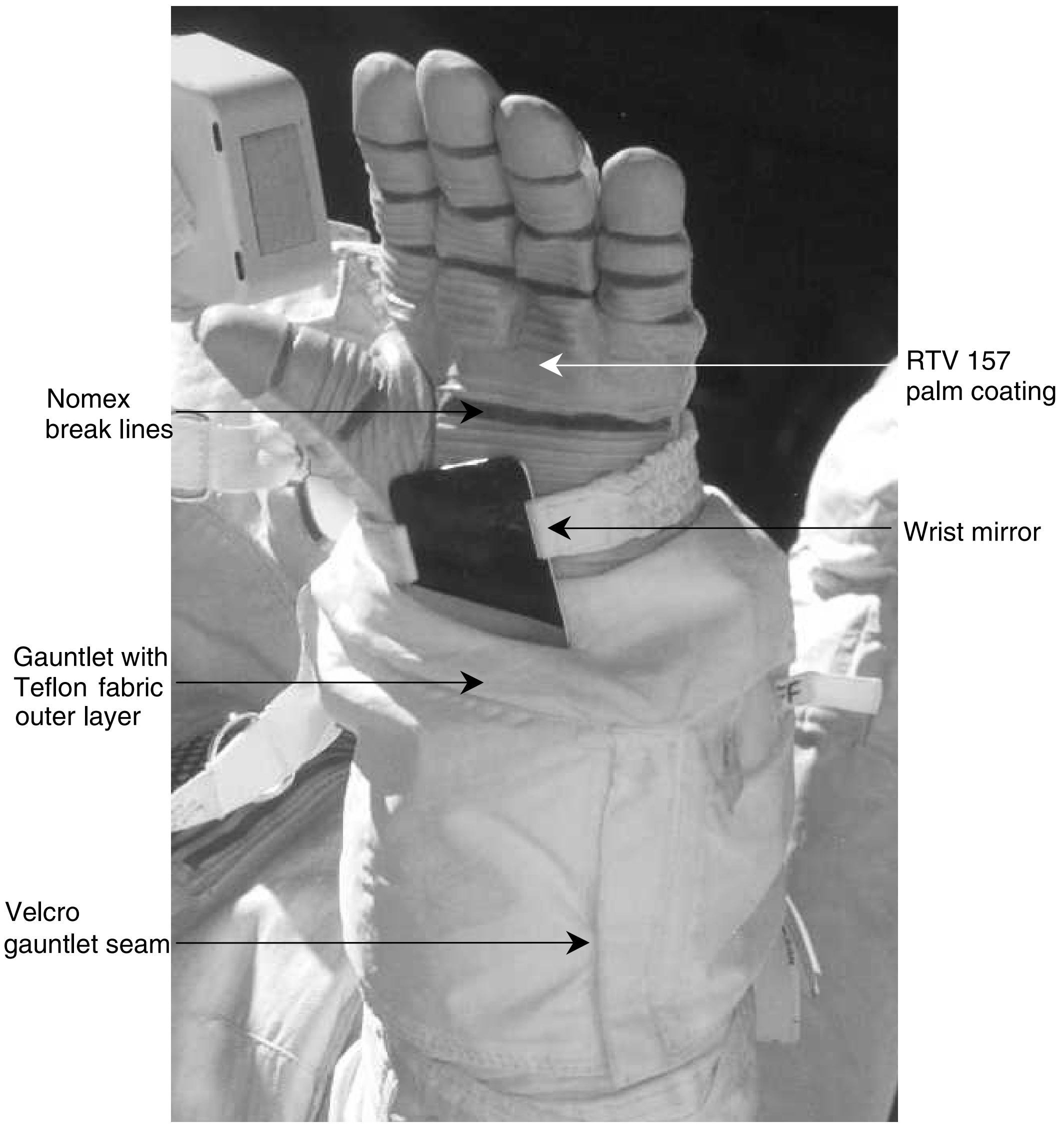


Figure 2-25. 4000 series glove with 4750 TMG

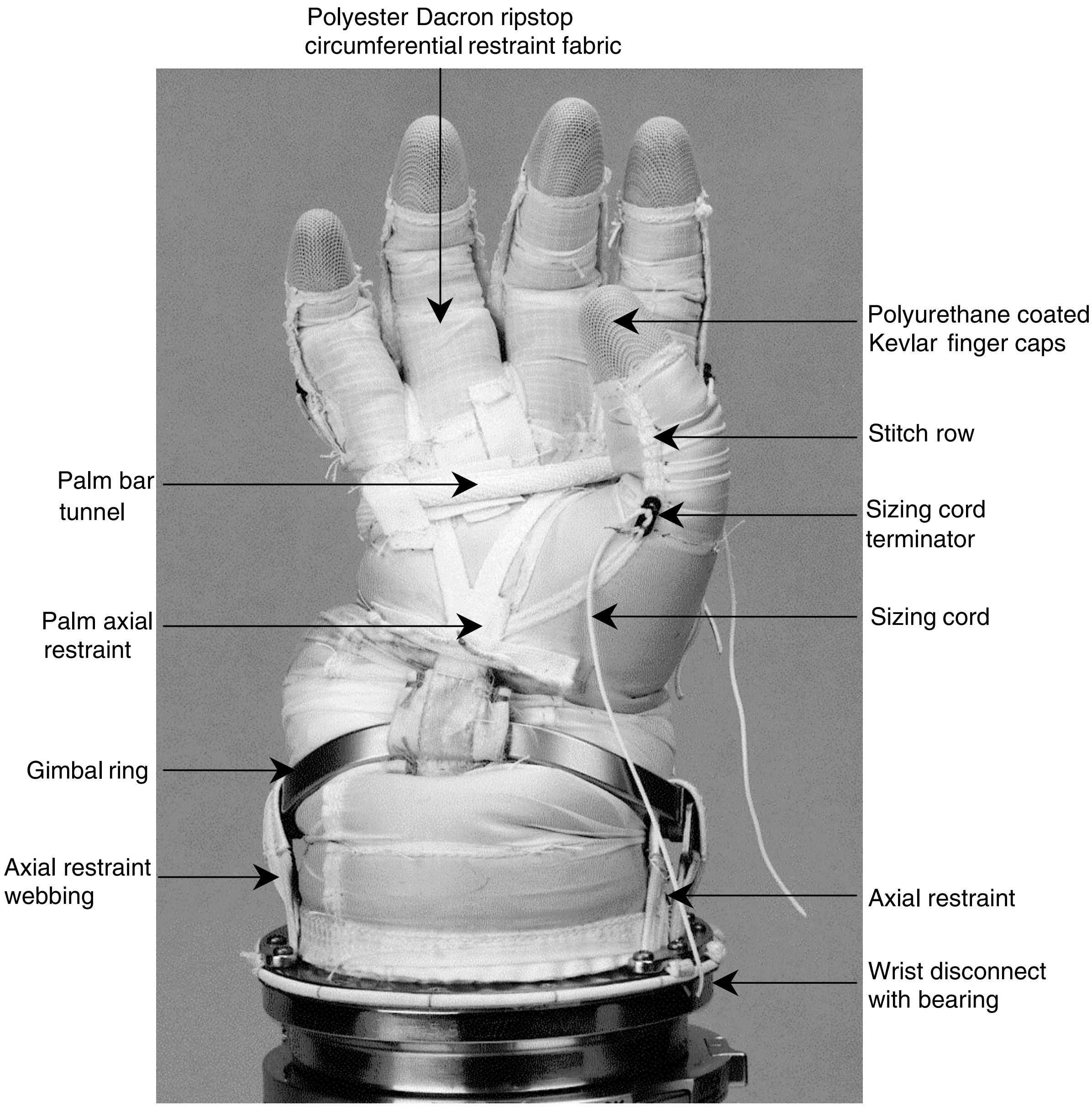


Figure 2-26. 4000 series glove without TMG

A green-pigmented, polyurethane bladder provides pressure integrity. The bladder is dipped, unsupported polyurethane with reinforcement patches in the thumb and finger crotches. Since the design of the bladder is oversized in comparison to the restraint, the bladder folds and creases when installed into the restraint. These folds and creases are distributed evenly and provide the length required for finger/wrist joint flexing. Unfortunately, these folds and creases also can create pressure points that irritate the hand. This condition is alleviated by wearing comfort gloves under the EV gloves to provide additional hand comfort (Section 5.4).

The glove restraint system contains a single gimbal ring for wrist mobility. The gimbal ring also transfers all axial forces applied to the finger/palm area to the wrist bearing/disconnect by means of restraint webbing. Radial loading within the palm area is controlled by means of an adjustable palm restraint assembly that prevents ballooning of the palm area in order to maintain grasping capabilities. Essentially, the palm restraint assembly acts like an adjustable belt around the metacarpals. This assembly consists of a malleable 300 series stainless steel bar sheathed in a palm bar tunnel, which consists of a double layer of polyester webbing folded and stitched together. A buckle and a cinch strap on the ends of the webbing enable the crewmember to tighten the palm restraint assembly against the hand as required for mobility and comfort (Figure 2-27). Adjustment of the tightness of the palm restraint strap is performed on orbit and during training just prior to suit pressurization. Axial positioning of the palm restraint assembly relative to the metacarpals can be accomplished during ground processing by selecting different routing loops located both on the front and back of the glove restraint palm. Currently, there are 18 possible positions that can be selected to enhance crew comfort and mobility.

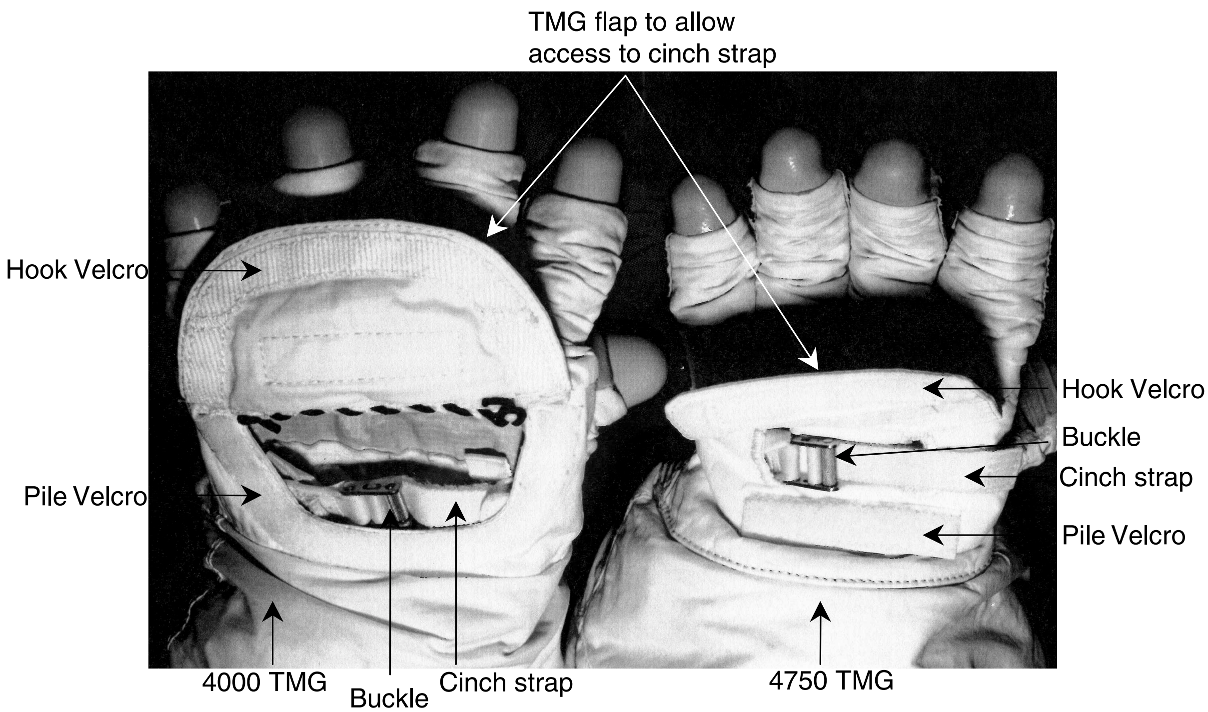


Figure 2-27. Palm bar cinch straps and buckles

A TMG covers the exterior of the glove restraint/bladder assembly for protection from the environment and the work area. In an attempt to prevent hindering crewmember mobility due to excessive bulk, the design of EV glove TMGs differs from the design of TMGs used to cover other parts of the EMU; micrometeoroid protection is not provided, and the level of thermal protection has been reduced. This design optimizes crewmember mobility while providing adequate protection for the majority of EVA tasks. Currently, there are multiple

TMG configurations certified for flight as part of the 4000 series glove design (described in detail below). The design contains the several generic features. As an aid to gripping, an RTV silicone abrasion-resistant coating is applied to the palm and finger/thumb front surfaces. Attached to the hand portion of the TMG is a cone-shaped shroud referred to as the gauntlet. The purpose of the gauntlet is to provide protection to the wrist area and wrist disconnect. A wrist tether loop, the attach point for the EVA wrist tether, is designed to withstand a maximum of 30-150 lbf. The strap attaches to the wrist disconnect and passes through a buttonhole in the gauntlet of the glove TMG. A flap, located on the back of the TMG hand, provides access to the palm restraint assembly for tightness adjustment purposes.

The original TMG design for the 4000 series EV glove is known as the 4000 series TMG. This TMG is still used for contingency EVA flights. The main design points are as follows:

a. Molded Kevlar-reinforced RTV finger and thumb caps are sewn onto the fingers to provide insulation with good tactility.

b. RTV silicone coats the entire palm, finger, and thumb fronts to enhance gripping.

c. Felt insulation is contained on the interior of the thumb, index, and middle finger caps along with the palm metacarpal area.

The 4750 TMG provides design enhancements over the 4000 series TMG. The main enhancements are as follows:

a. One-piece Nomex fabric finger fronts and caps, which are coated with RTV silicone.

b. Break points are in the RTV silicone that coats the finger, thumb, and palm fronts, thus exposing the Nomex base fabric at the joint location to reduce flexing torque.

c. Felt insulation is contained on the interior of all thumb and finger caps, along with the palm metacarpal area.

d. Gores are added to the thumb for increased mobility.

There is also a heated version of the 4750 TMG used in conjunction with the base 4000 series restraint/bladder to create the heated glove assemblies. See Section 2.4.1 for information on the remote powered heated glove assembly.

2.3.2 Phase VI Glove Assembly

The phase VI glove is the result of an advanced development effort to enhance mobility performance characteristics and to improve TMG performance by incorporating advanced patterning, technology, and manufacturing improvements (Figure 2-28). The glove design is truly customized to fit the recipient. Unlike the previous glove designs, there currently is not a standard sizing system for phase VI gloves. Instead, each phase VI glove is anatomically designed for a specific crewmember. However, in the event that numerous crewmembers have very similar anthropometric measurements, common glove sizes may be used. Specific fit adjustments, within a certain glove size, can be achieved during ground processing by changing the length of individual fingers using a pair of polyester Dacron cords. These cords are routed around the sides and top of the restraint finger/thumb, and sizing is accomplished by adjusting these cords in a drawstring fashion. The full range of adjustment is approximately 1/2 inch.

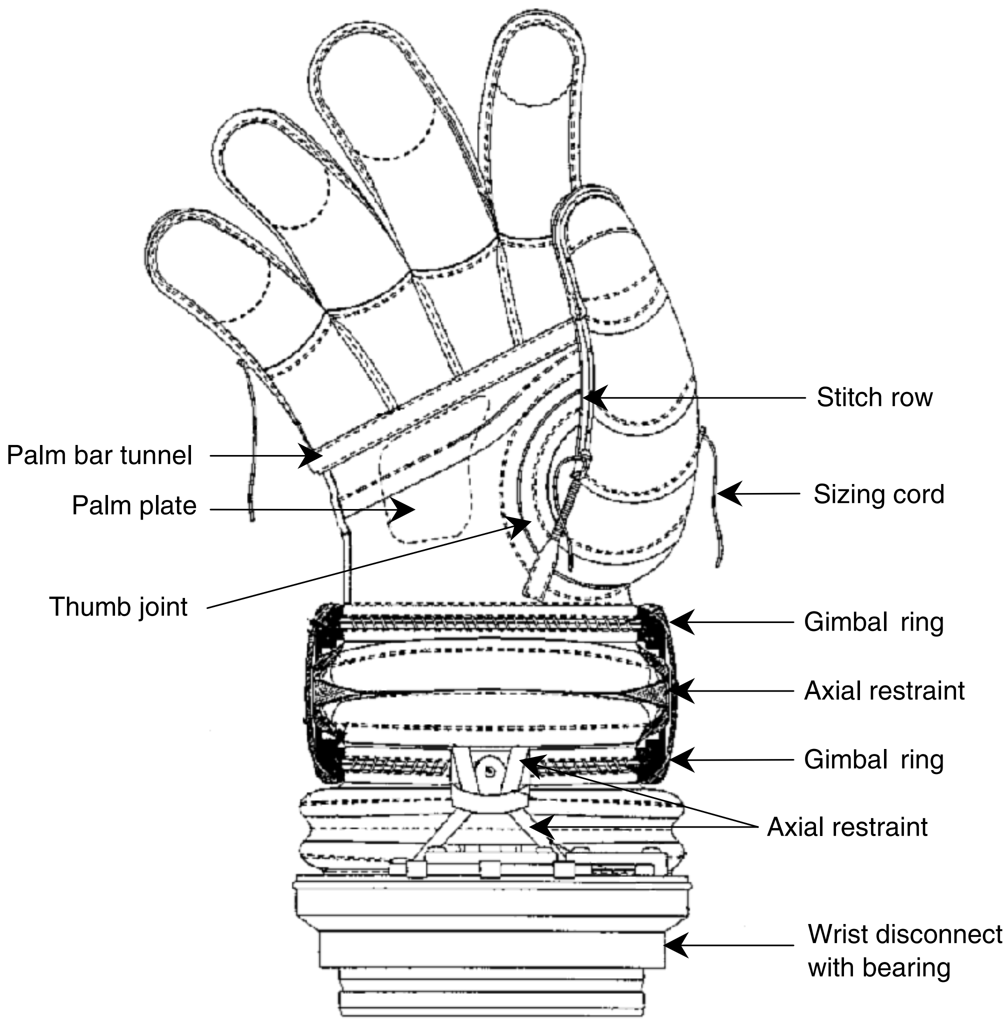


Figure 2-28. Phase VI glove without TMG

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A green-pigmented, low easement (tight fitting), convoluted bladder provides pressure integrity. The bladder is dipped, unsupported polyurethane with reinforcement patches in the thumb and finger crotches. Bladder convolutes are located on the backside of the fingers and in the wrist area. These convolutes provide the extra length required for joint flexing and wrist mobility. Bladder convolutes are positioned with anatomical accuracy on top of the joint to optimize mobility and torque. The convolutes also increase crew comfort by eliminating excess bladder folds that cause pressure points (oversized bladders were previously used to obtain lengths for mobility). With the convolutes providing only the minimum bladder length required for joint movement, the rest of the bladder can be more closely fitted into the glove restraint, thereby practically eliminating the folds and creases and the pressure point problem. This allows for a tighter fitting glove. The bladder is integrated into the restraint and both are flange mounted to the wrist disconnect.

The most important difference between the phase VI glove restraint and previous EV gloves is that the phase VI actually has a thumb (carpo-metacarpal) joint. The presence of this joint increases thumb mobility and range of motion, again improving crew grasp capabilities. Other phase VI glove restraint enhancements include a soft wrist design and an improved palm restraint assembly. The soft wrist design resulted from evaluation of the glove/wrist on the Russian Orlan suit, plus mobility range improvements. The pressurized phase VI wrist fabric geometry is more controlled than previous glove designs. The control is supplied by combining fabric convolutes, circumferential webbing, and a dual gimbal ring design. The position of the wrist flexion/extension axis is better aligned to the anatomical flex/ex axis, which reduces the force input required by the crewmember for joint movement. The gimbal rings transfer all axial forces from the finger/palm area to the wrist bearing/disconnect by means of restraint webbing.

The phase VI glove restraint also contains an improved palm restraint system to prevent the palm area of the glove from ballooning when pressurized. This system contains both a palm bar and a palm plate. The bar is fabricated to the shape of the hand of the crewmember. It is made from 17-4PH stainless steel (stiffer than that on the 4000 series glove), which minimizes deflection under pressurization. The bar is housed in a webbing sheath/strap sewn directly to the restraint at a location that is aligned with the metacarpal joints of the crewmember. A buckle and a cinch strap on the ends of the webbing enable the crewmember to tighten the palm restraint assembly against the hand as required on orbit and during training, for mobility and comfort. Adjustment of the palm restraint strap tightness is performed just prior to suit pressurization on orbit and during training. Besides the bar, a composite palm plate helps to maintain the restraint in a more conformal palm shape and thus allows for better grasping capabilities.

Crew protection from the environment is maintained by the phase VI glove TMG (Figure 2-29). However, this TMG is designed to be more conformal to the restraint by means of a one-piece, vacuum-formed knitted palm. RTV silicone pad strips are applied to the finger/thumb fronts and palm for gripping. Felt insulation is contained on the interior of all thumb and finger caps along with the palm metacarpal area. Attached to the hand portion of the TMG is a cone-shaped shroud, referred to as the gauntlet, which offers protection to the wrist area and wrist disconnect. A wrist tether loop is the attach point for the EVA wrist tether; it is designed to withstand a maximum of 30 to 150 lbf. The strap attaches to the wrist disconnect and passes through a buttonhole in the gauntlet of the glove TMG. A flap, located on the back of the TMG hand, provides access to the adjustment strap of the palm restraint assembly for tightening purposes. Heating elements are located in the fingertips, and switch circuitry is on the back of the hand that works in conjunction with the SSA Power Harness (see Section 2.4).

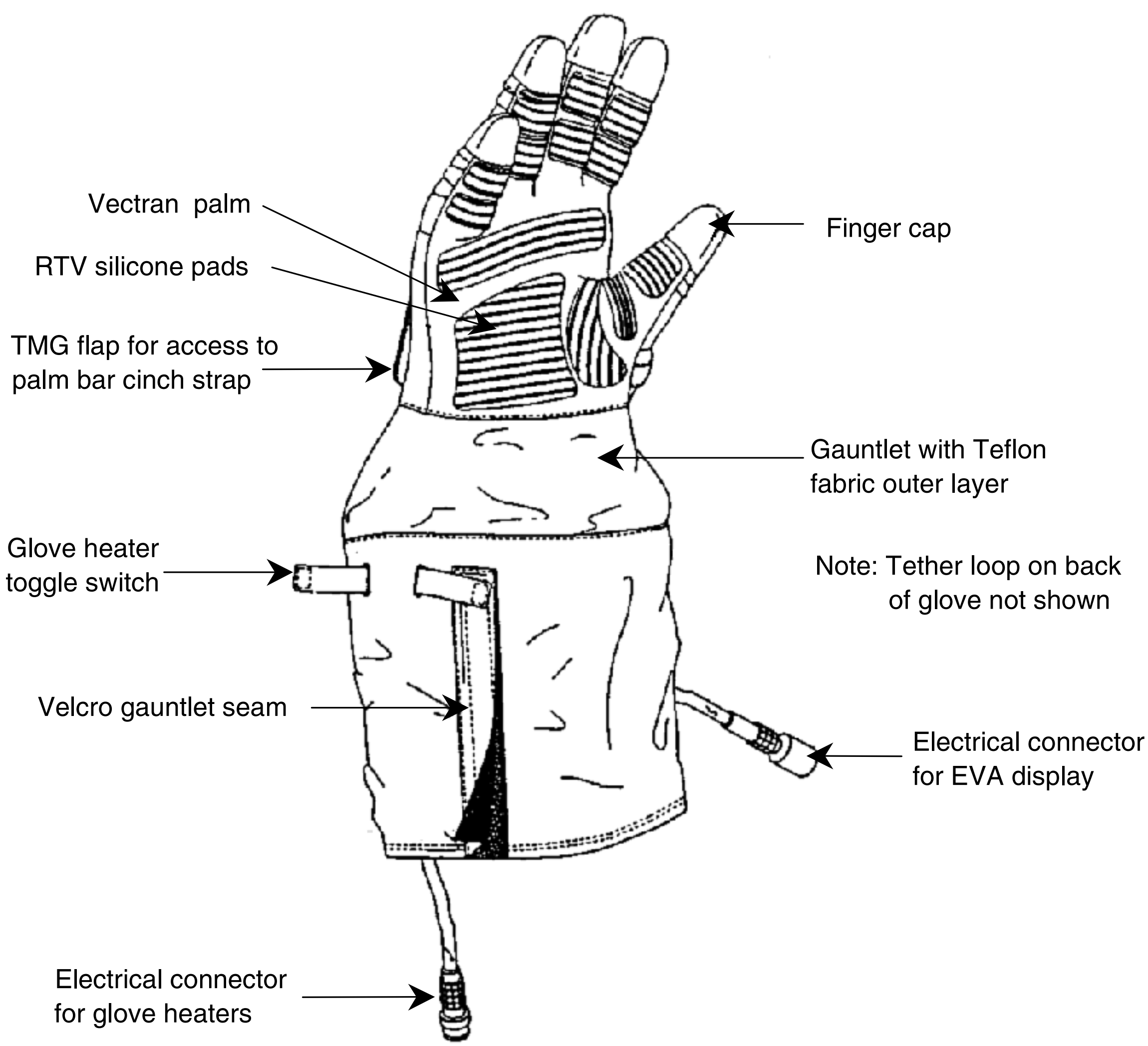

Figure 2-29. Phase VI glove TMG

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To accommodate International Space Station needs, the phase VI glove TMG and the 4750 TMG on the 4000 series glove have been designed as ORUs. The requirement for a replaceable TMG is driven by damage occurring from the work environment, such as cuts and nicks of the RTV silicone. Currently, these conditions are repaired through normal ground processing, but these repair procedures are not certifiable for on-orbit conditions. Replacement of a TMG will occur after approximately five to six EVAs or when warranted by the condition of the TMG.

2.3.3 Glove Side Wrist Disconnect

Both the 4000 series and phase VI EV glove designs interface with a stainless steel dual seal wrist disconnect. The flanges of both the bladder and the restraint mount under a clamping ring on top of the wrist disconnect. This disconnect is the passive half that mates with the suit side (arm) wrist disconnect element. The glove disconnect also includes a dual seal wrist bearing to provide wrist rotation.

2.4 SSA Power Harness (SSAPH) System

The SSA Power Harness System consists of the following components:

a. One pair of heated glove assemblies (4000 series or phase VI)

b. Two battery assemblies

c. One modified SEMU with power harness

The system provides active heating at the fingertips of the heat glove assemblies. This system can be activated by a single crewmember as needed during the EVA.

2.4.1 Remote-Powered Heated Glove Assembly

The original heated glove assemblies consist of a modified 4000 series glove design with a 4750 series TMG containing heater circuitry and a modified TMG gauntlet to accommodate switches and wire harnesses. The inherent design of the phase VI glove assembly includes these heating components. Both assemblies are 3V systems.

The electrical heating elements are mounted on the inside surface of each finger/thumbtip of the TMG and provide approximately 0.5 watts of power. These elements are commercial 21.1-ohm thermofoil heaters modified for use with the EV glove. They are wired in parallel to a two-position toggle switch that is hermetically sealed. The switch is mated to a male 7-pin Lemo connector (Figures 2-30 and 2-31). The switch is crimped to thermofoil heater wires and is activated by the crewmember pulling on a fabric on-off tab that extends through the gauntlet. The remaining five pins of the heater assembly Lemo connector will be used in the future to power the EVA display (Electronic Cuff Checklist).

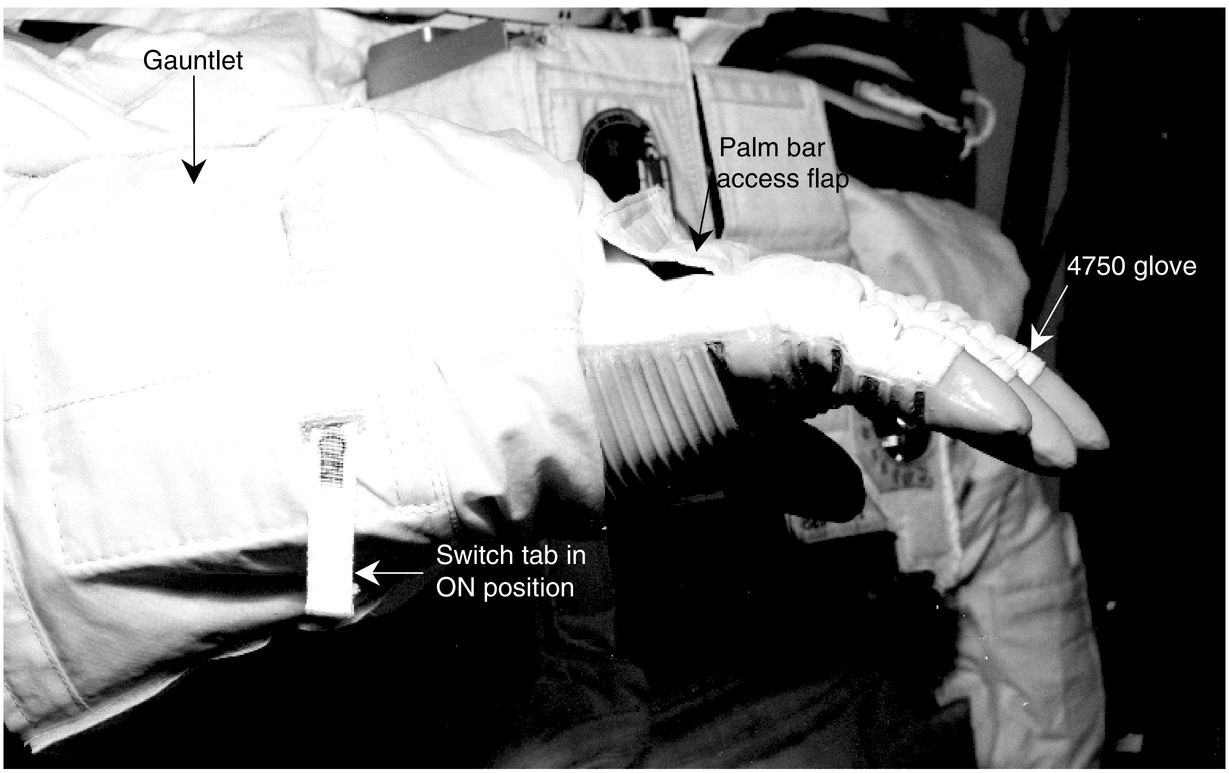

Figure 2-30. Glove heater switch in ON position

Figure 2-31. Glove heater Lemo connector

2.4.2 Battery Assembly

The SSAPH battery pouch is located below the right arm of an EV crewmember and laced between the HUT and PLSS TMG (Figure 2-32). Housed in the SSAPH battery pouch are two lithium BCS I D-cell batteries, one for each glove (Figure 2-33). Each battery has a 1.5-amp pico fuse, two hermetically sealed, shunt-type thermostats that open at 72° C, and a female electrical Lemo connector to allow for easy changeout of battery packs (Figure 2-34). The switch assembly consists of a two-position, hermetically sealed toggle switch for each of the two batteries. The switch is activated by the IVA crewmember by pulling on a fabric on-off tab that extends through the pouch (Figure 2-35).

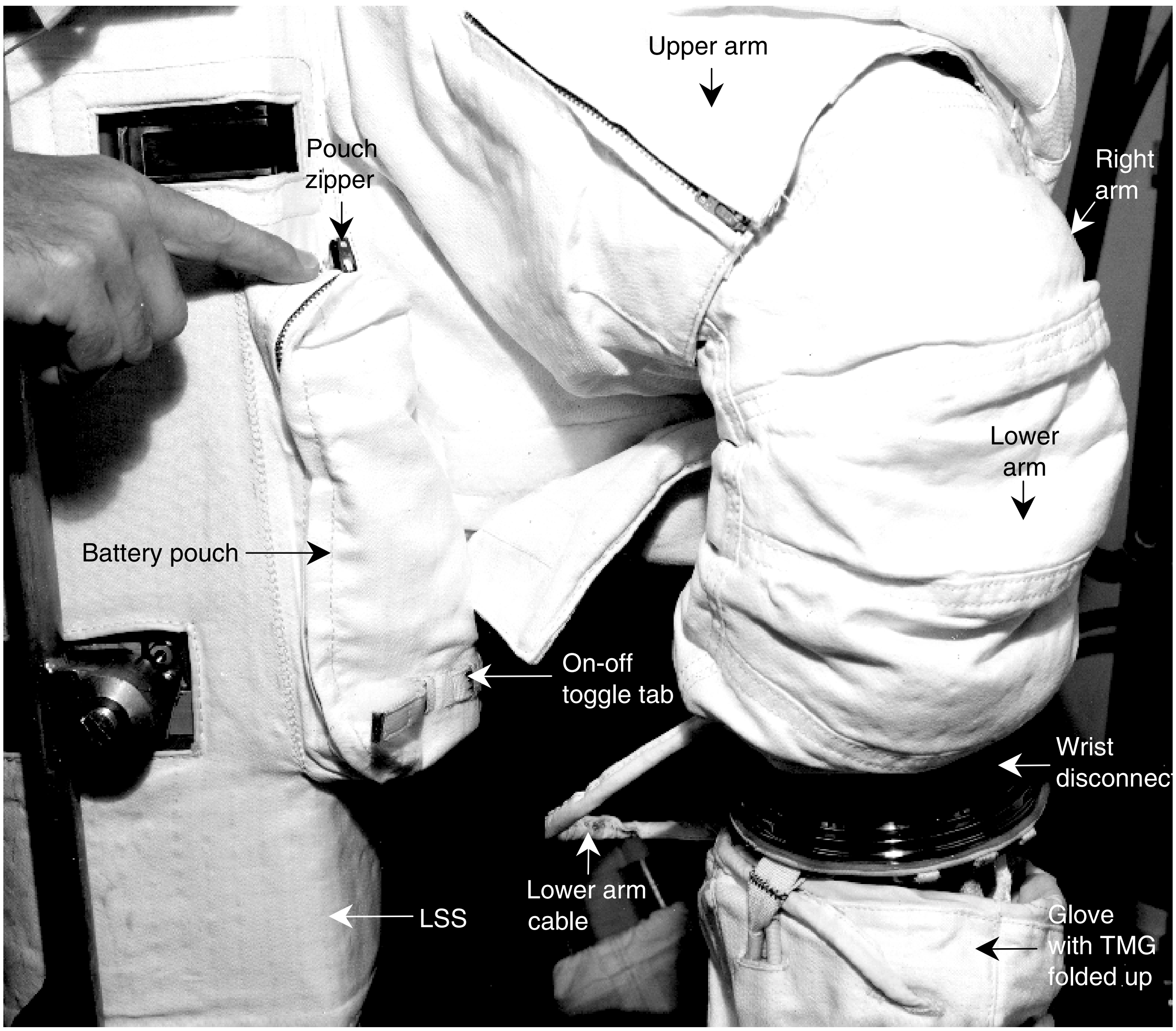

Figure 2-32. SSAPH battery pouch

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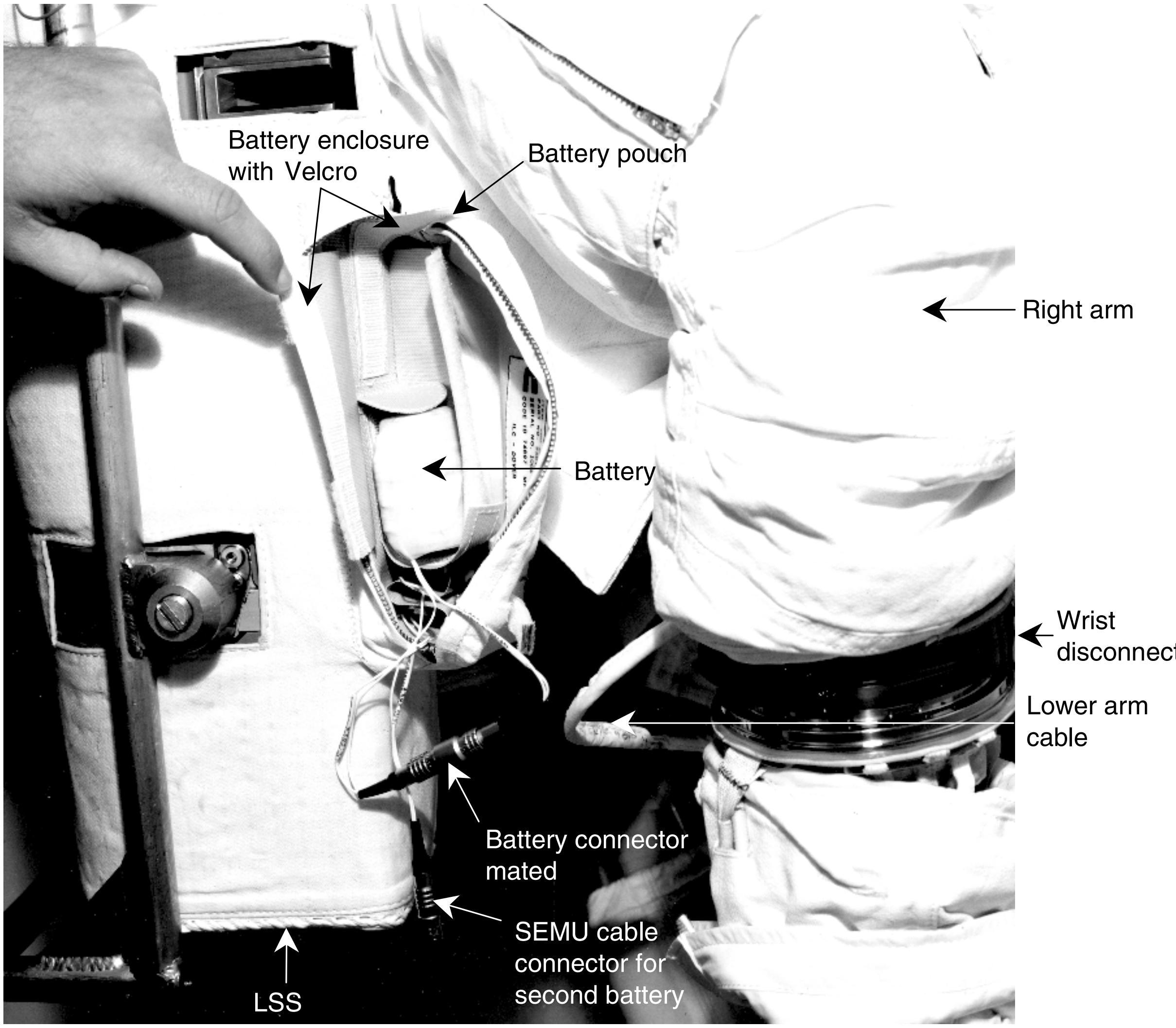

Figure 2-33. SSAPH with one battery

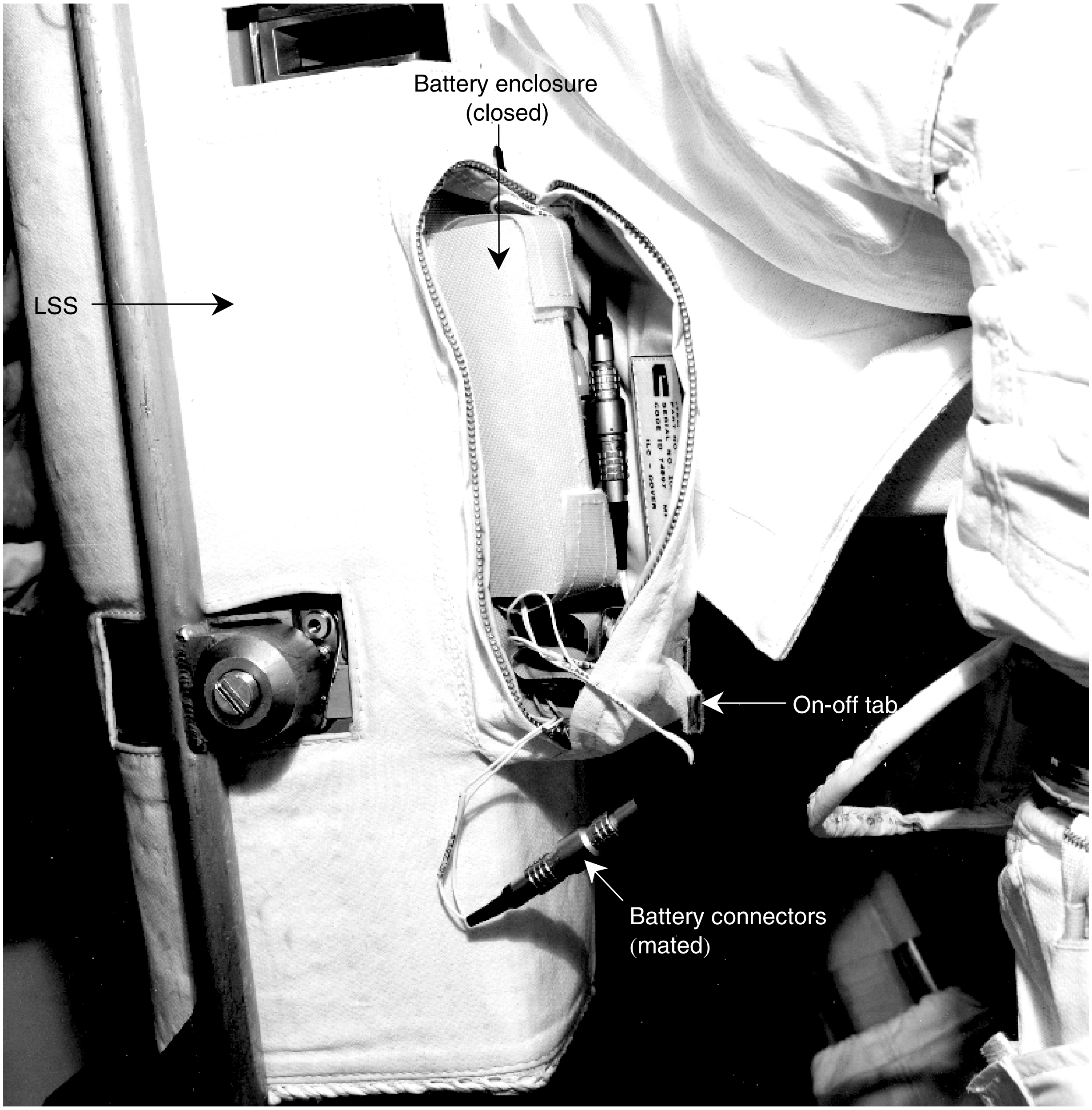

Figure 2-34. SSAPH with two batteries

Figure 2-35. SSAPH on-off tab

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2.4.3 Modified Short EMU

In addition to the SSAPH battery pouch, a cable harness system is added to the SEMU to provide a means for transferring power to the glove heaters. In order not to impede the on-orbit resizing capability of the enhanced SSA, the cable harness system consists of two separate cables that mate at the SSA upper/lower arm interface. The SSAPH lower arm cable mates with the remote-powered heated glove at the 7-pin Lemo (Figure 2-31). The SSAPH lower arm cable is in turn connected to a SEMU cable. Both these cables consist of three smaller cables, each of which houses shielded twisted pairs of 24-gauge wire. The SEMU cable assembly terminates at the SSAPH pouch. The cable harness system is routed underneath the arm and HUT TMGs to prevent snag points.

2.5 Helmet/Extravehicular Visor Assembly (EVVA)

The helmet, which is “one-size-fits-all,” consists of a detachable, transparent, hard pressure vessel encompassing the head (Figure 2-36).

The helmet includes the following components:

a. Hard transparent bubble

b. Helmet disconnect ring (passive half)

c. Helmet purge valve

d. Vent pad

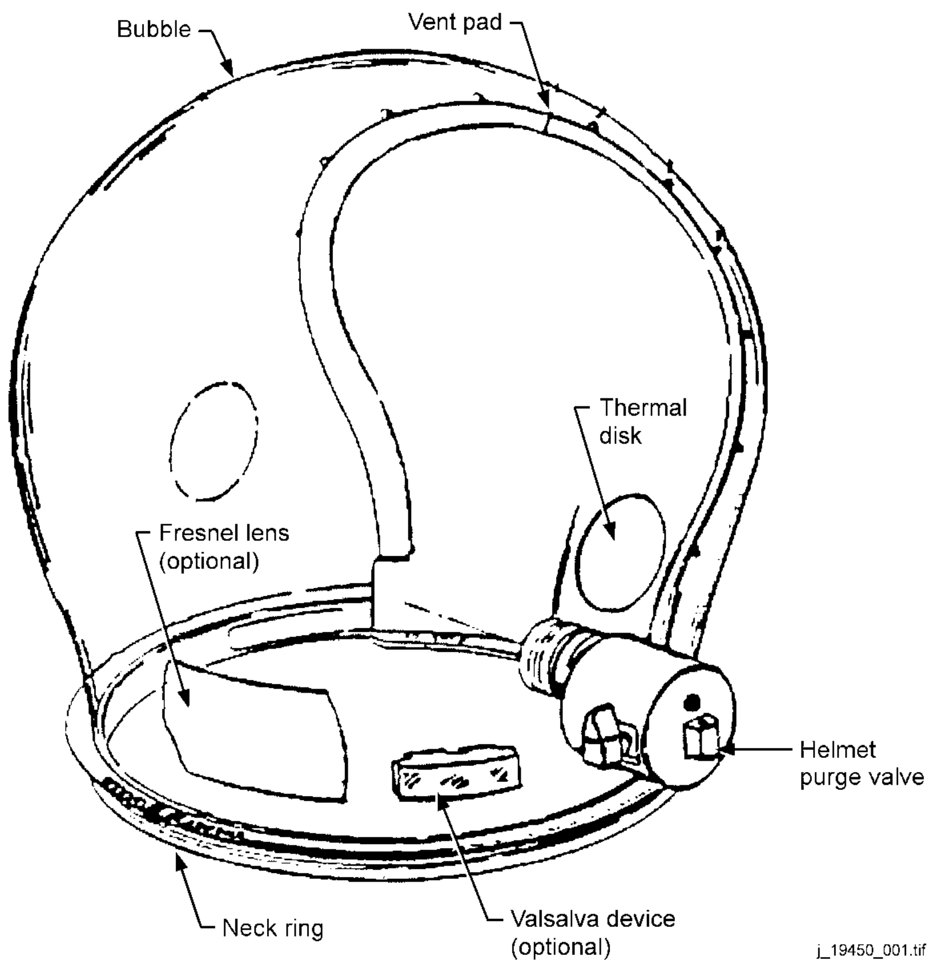

Figure 2-36. Helmet drawing

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The helmet bubble is made from a clear formed polycarbonate that is ultraviolet stabilized. Thermal disks are bonded to the outside of the bubble, one on each side, to reflect heat from the EVVA pivots. The bubble is bonded and sealed to an aluminum neck ring. The rear of the neck ring contains a shelf with an opening that aligns with the O_2 vent duct on the HUT half of the neck ring. The shelf contains a blank area that can be used to block flow from the vent duct in the HUT when the helmet is installed in the NO VENT position. The NO VENT position was used to seal the O_2 ventilation circuit for checkout of the SOP. This helmet position is no longer used. SOP checkout is now performed with the SOP Checkout Fixture (SCOF) installed in the HUT half of the neck ring (discussed in Sections 3.2 and 4.12). Marks are provided on both halves of the neck ring to visually check for correct alignment of the duct during helmet donning (Figure 2-4 in Section 2.1). The neck ring also has rotation stops to prevent accidental rotation of the helmet into the NO VENT position, which would shut off vent flow.

The opening in the shelf leads to a helmet vent pad made of white polycarbonate that is mounted in the back of the helmet. Its purpose is to direct vent flow from the neck ring duct over the top of the crewmember's head and across the front of the helmet bubble (Figure 2-37). The flow is deflected by vanes in the rear of the pad to provide an even flow all over the helmet. This serves to ensure the crewmember an adequate O_2 supply to the front areas of the helmet and to minimize helmet fogging. A wipe-on antifog compound is applied to the inside of the helmet to provide additional protection.

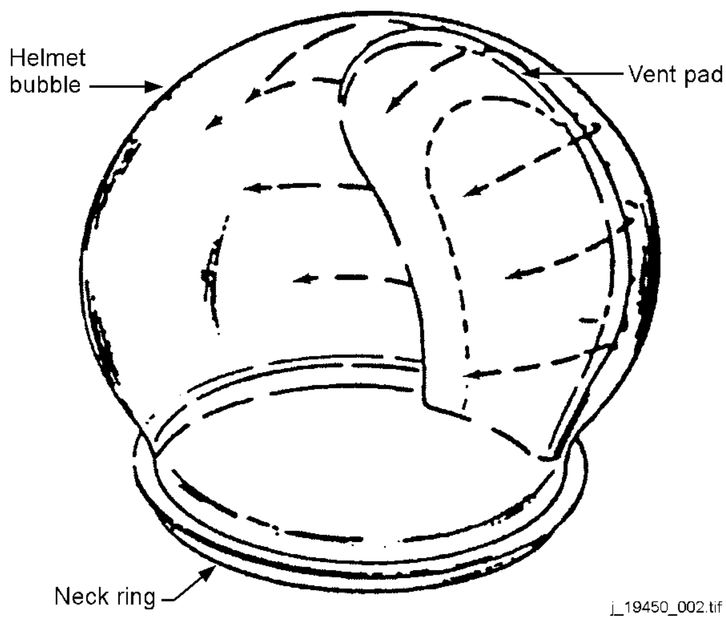

Figure 2-37. Helmet vent flow

The helmet purge valve is bolted to and penetrates the side of the helmet, just aft of the left corner of the mouth. This valve provides suit purge capability. It has an orifice that will flow up to 2.5 lb/hr of O_2 when open. To unlock the valve, depress the lever and rotate it 90° outboard to the unlocked position. To open the valve, rotate the housing 50° forward to open the orifice (Figure 2-38). To close the valve, rotate the housing 50° rearward to close the orifice. The valve should be locked in both the fully open and fully closed positions so that the flow rate is known (Figure 2-39). To lock the valve, depress the lever and rotate it 90° inboard. The crewmember can see the word “LOCKED,” which is printed on the locking lever, from inside the helmet when the valve is locked (Figure 2-40).

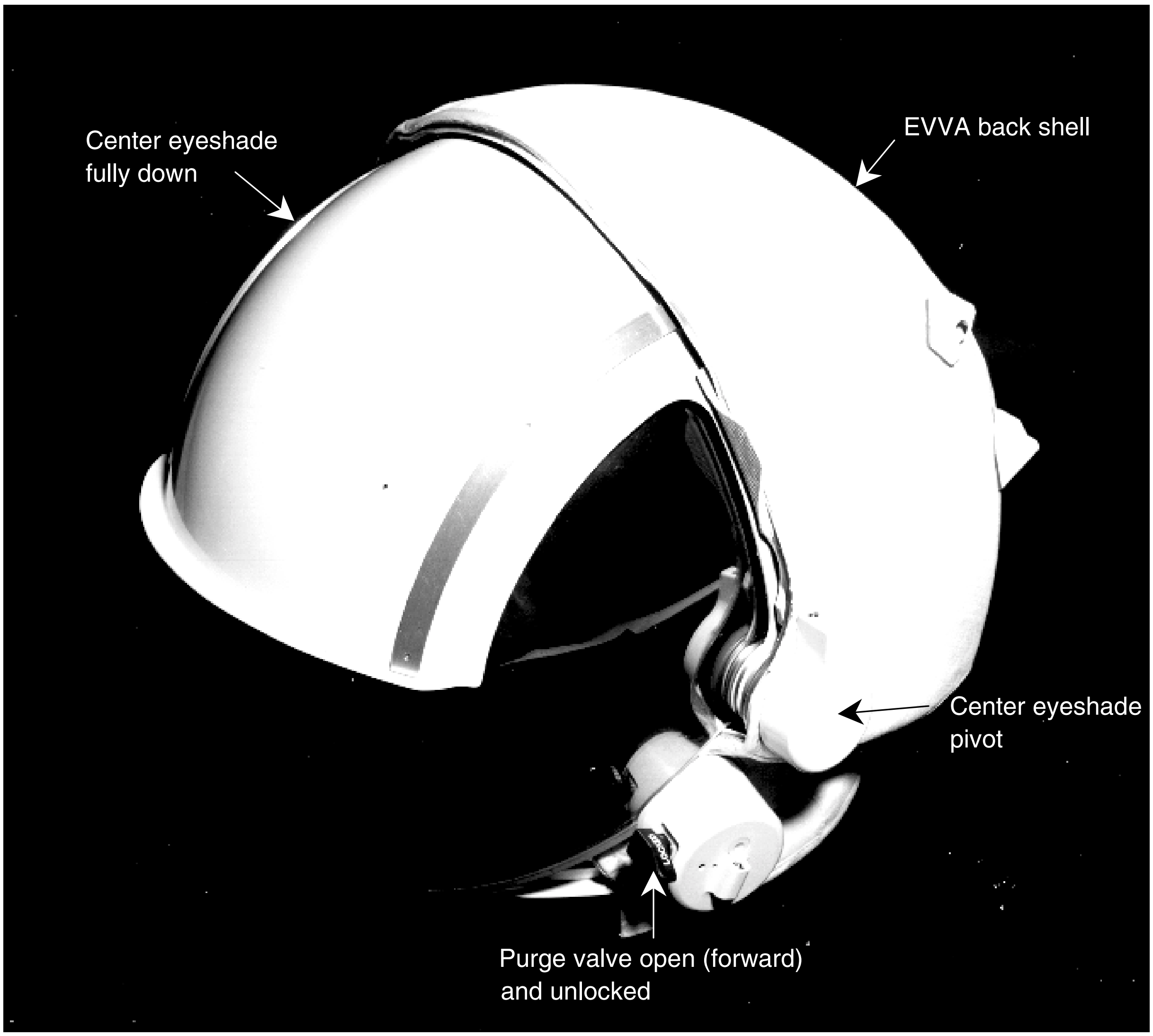

Figure 2-38. Helmet purge valve open and unlocked

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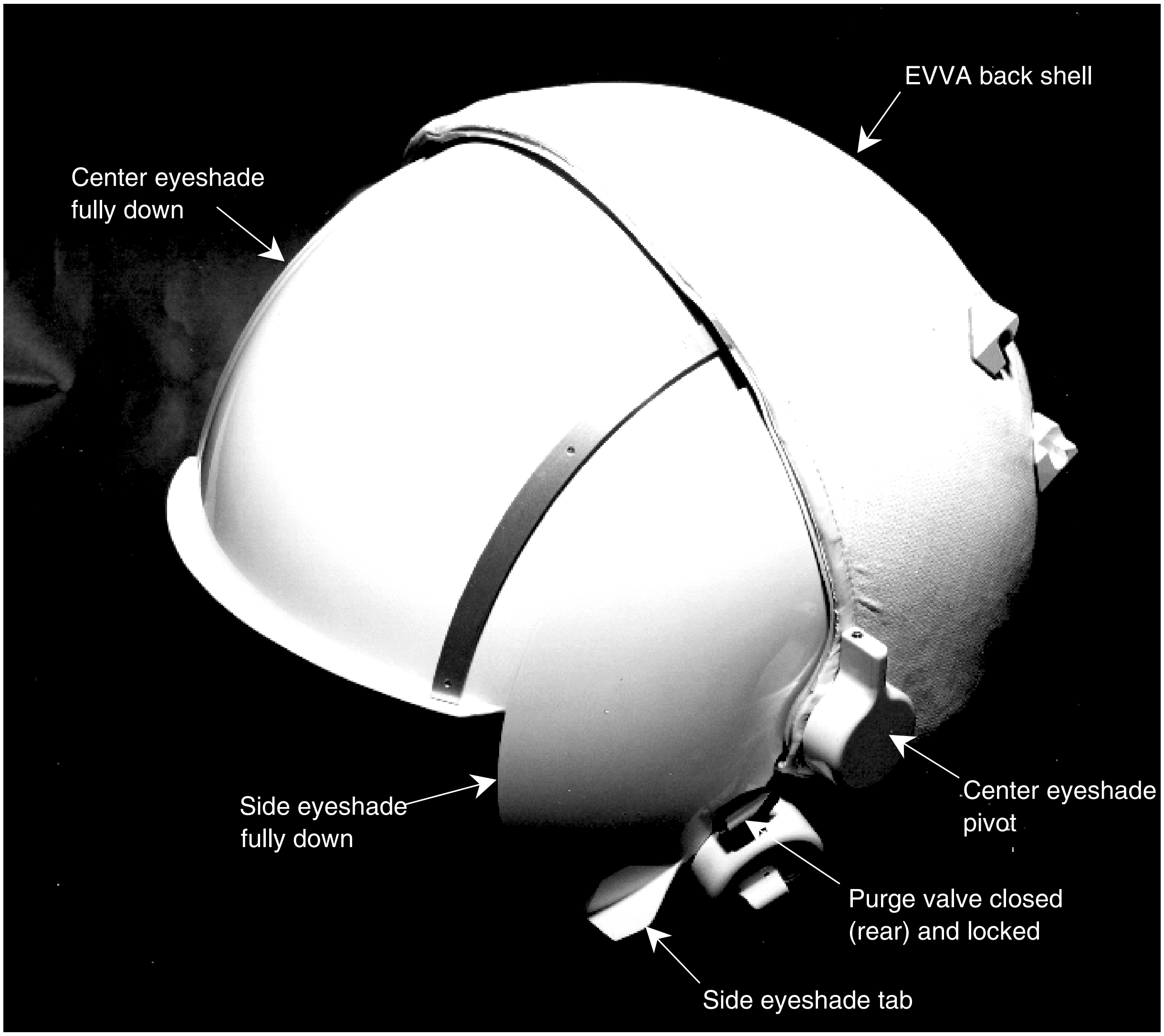

Figure 2-39. Helmet purge valve closed and locked

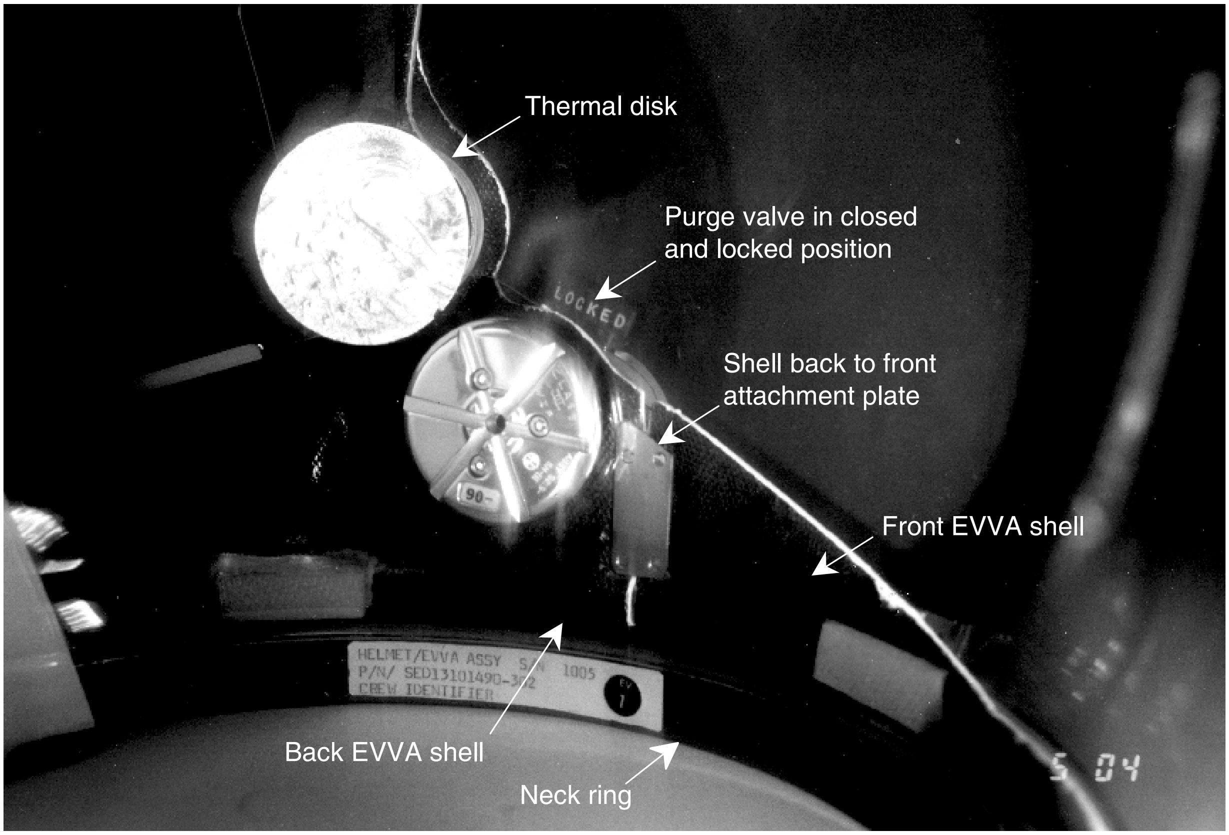

Figure 2-40. Helmet purge valve from inside helmet

The EVVA attaches to the helmet to provide the crewmember with visual, thermal, impact, and micrometeoroid protection (Figures 2-41 and 2-42).

The EVVA includes the following components:

a. Shell

b. Protective visor

c. Sun visor

d. Center and side eyeshades

e. TMG

f. Pivot and latch mechanisms and supporting structures for the visors and eyeshades

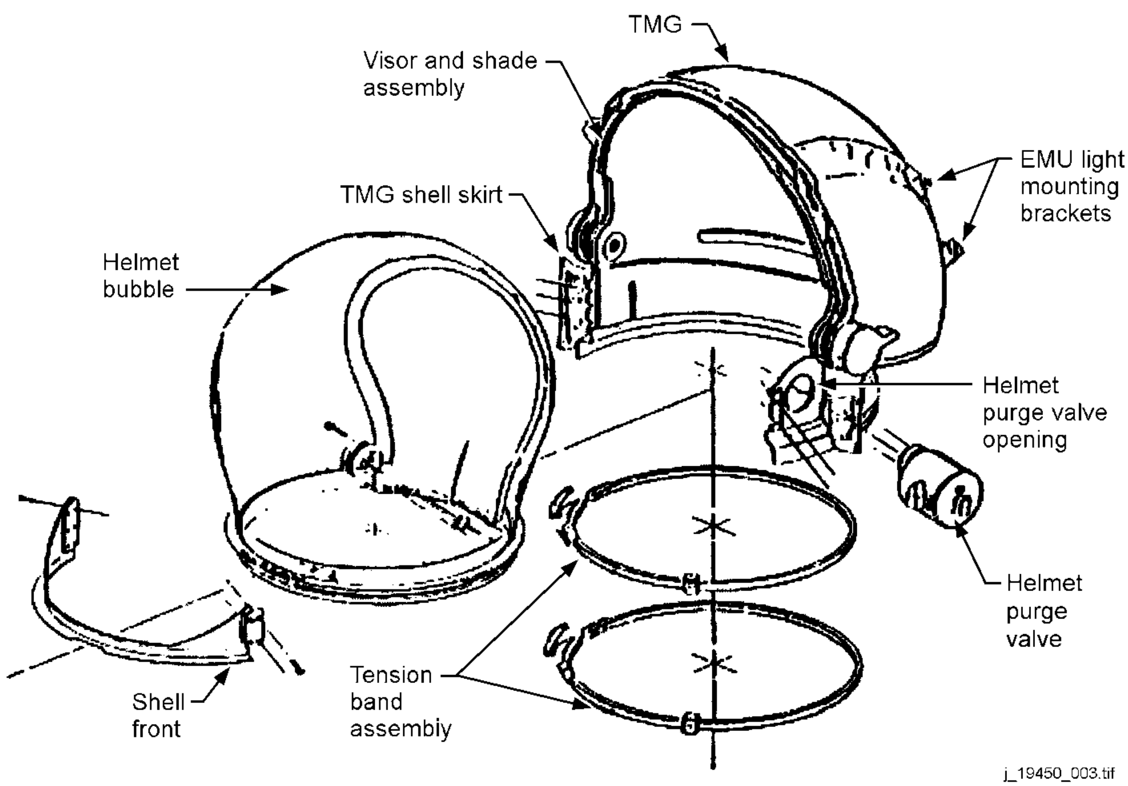

Figure 2-41. EVVA drawing

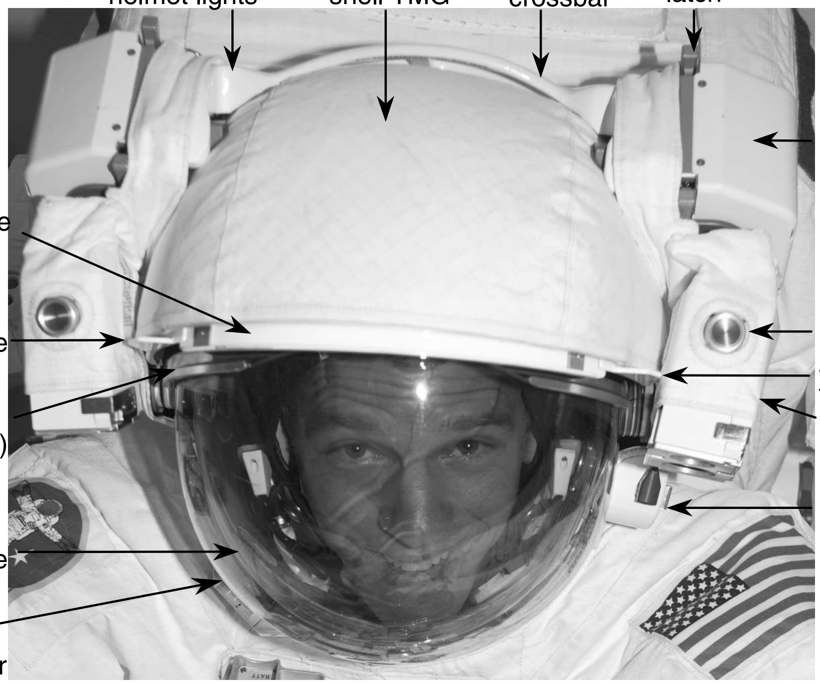

Figure 2-42. EVVA photo

The EVVA shell is made in two parts. The back portion of the shell is formed from a polycarbonate sheet. The front part of the shell is made of fiberglass and is attached to the back shell by stainless steel plates. A hole in the left side of the back shell is provided for the helmet purge valve. The back shell also contains internal slide tracks for the center eyeshade and external brackets for the EMU lights. A TMG is conformally fitted to the shell for thermal control.

The innermost visor in the EVVA is a clear protective visor. This visor, which is formed from an ultraviolet-stabilized polycarbonate sheet, is not adjustable and remains in the full-down position. Both the outer and inner surfaces of the protective visor are hardcoated for scratch resistance. Also, the inner surface is thinly coated for thermal and optical protection.

The next visor (in order from the inside out) is the sun visor. It is formed from a polysulfone sheet. The outer surface is hardcoated for scratch resistance, and the inner surface is deposited with a new gold/bronze-colored Advanced Solar Control Coating (ASCC). The ASCC, a proprietary mixture of materials, replaces the previous gold coating on the sun visor. Some of its advantages over the gold coating include:

a. It passes less light at 450 nanometer (nm) wavelengths (blue region). This wavelength can be particularly damaging to the eye, so blocking more of it helps protect the eye.

b. It is a more robust, durable coating, and tests have shown that it can withstand more exposure to moisture. This is especially an advantage for long-duration ISS operations.

c. It attenuates more light overall.

The sun visor is operated with the pivot knob on the right side of the EVVA and can be positioned anywhere from the full-up to the full-down position.

Components of the EVVA, in combination with the polycarbonate helmet, serve as ultraviolet radiation barriers. The shorter wavelengths are most damaging, and different percentages are blocked by different parts of the helmet and EVVA. The polycarbonate of the helmet and the EVVA clear protective visor block 100 percent of UV radiation from 180 nm to approximately 360 nm; therefore, the shortest, most harmful rays (UVC, 200 to 290 nm, and UVB, 290 to 320 nm) are completely blocked. UVA rays range from 320 to 400 nm, so the shortest of those rays are also completely blocked. The EVVA sun visor blocks approximately 92 percent of the UV radiation in the 360- to 400-nm range. Of the 8 percent that passes, the EVVA clear protective visor blocks 60 percent, so less than 4 percent is passed to the helmet. Next, the helmet blocks 60 percent of that 4 percent and less than 2 percent of the UV radiation in the 360- to 400-nm range is passed to the crewmember.

Along with the visors, center and side eyeshades are provided (Figure 2-39). The eyeshades are made of fiberglass and are painted with Chemglaze paint. The left and right eyeshades are operated by the use of hand tabs on the side of each shade. The center eyeshade is operated by the rotation of the lever on the left side of the EVVA, located above the helmet purge valve. The center shade is guided by tracks on the inside of the EVVA shell, and the left and right shades are held in place by friction in the pivot points on each side of the EVVA shell. They can be adjusted to any position within their operating range. The center eyeshade will cover approximately one-half of the protective visor in the full-down position.

2.6 Liquid Cooling and Ventilation Garment

The LCVG is a form-fitting elastic garment worn against the crewmember's body (Figures 2-43 and 2-44). Its functions are to maintain the crewmember's thermal comfort while in the EMU and to return expired gasses to the PLSS for CO_2, contaminant, and odor removal.

The LCVG includes the following components:

a. Outer restraint fabric

b. Full torso zipper

c. Inner liner assembly

d. LCVG boot

e. Crew optional comfort pads

f. Biomed pocket

g. Dosimeter pocket

h. Water tubing network

i. Paramanifold assembly

j. Ventilation ducting network

k. Vent plenum assembly

l. Multiple water connector (passive half)

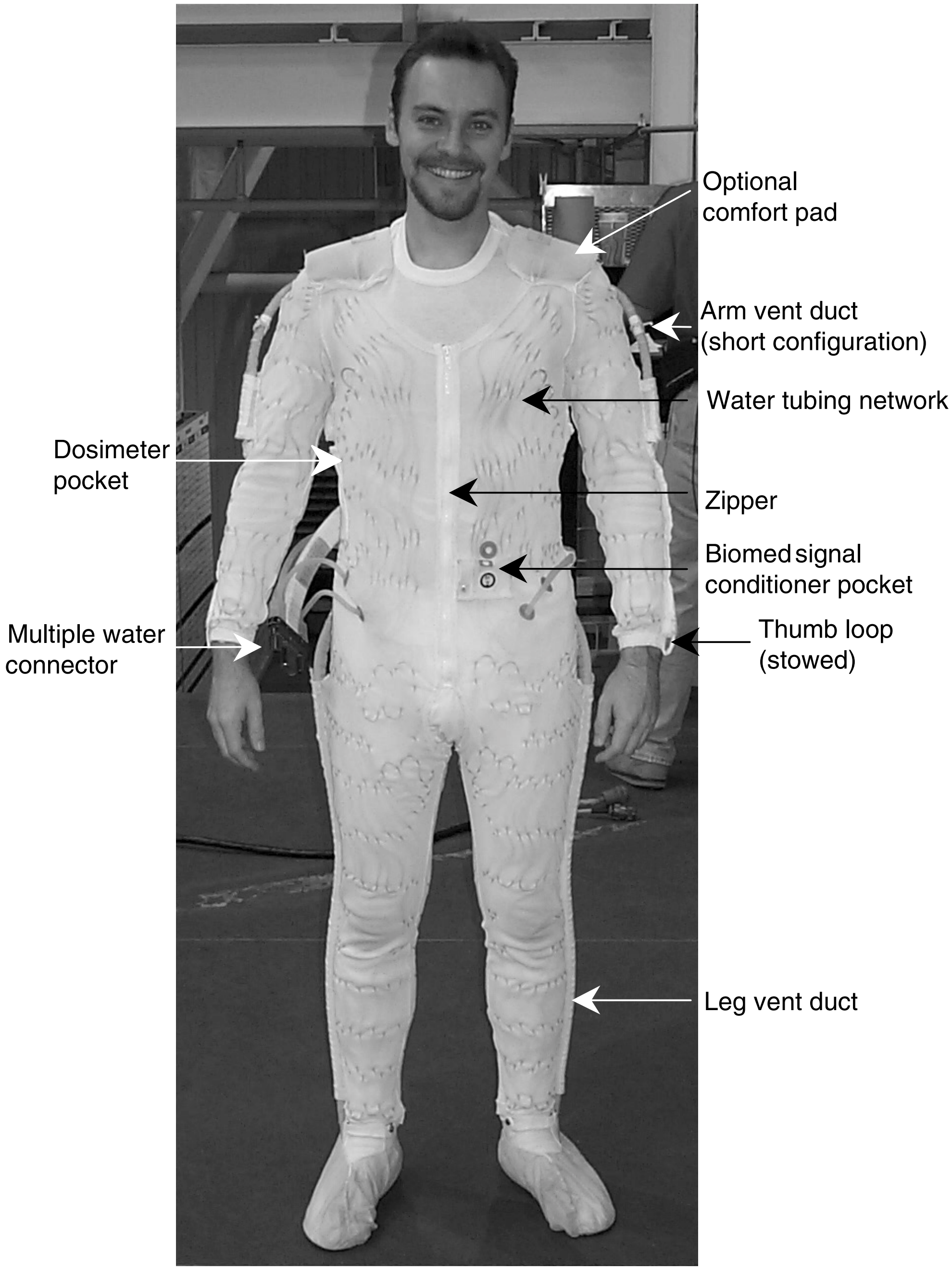

Figure 2-43. LCVG, front view

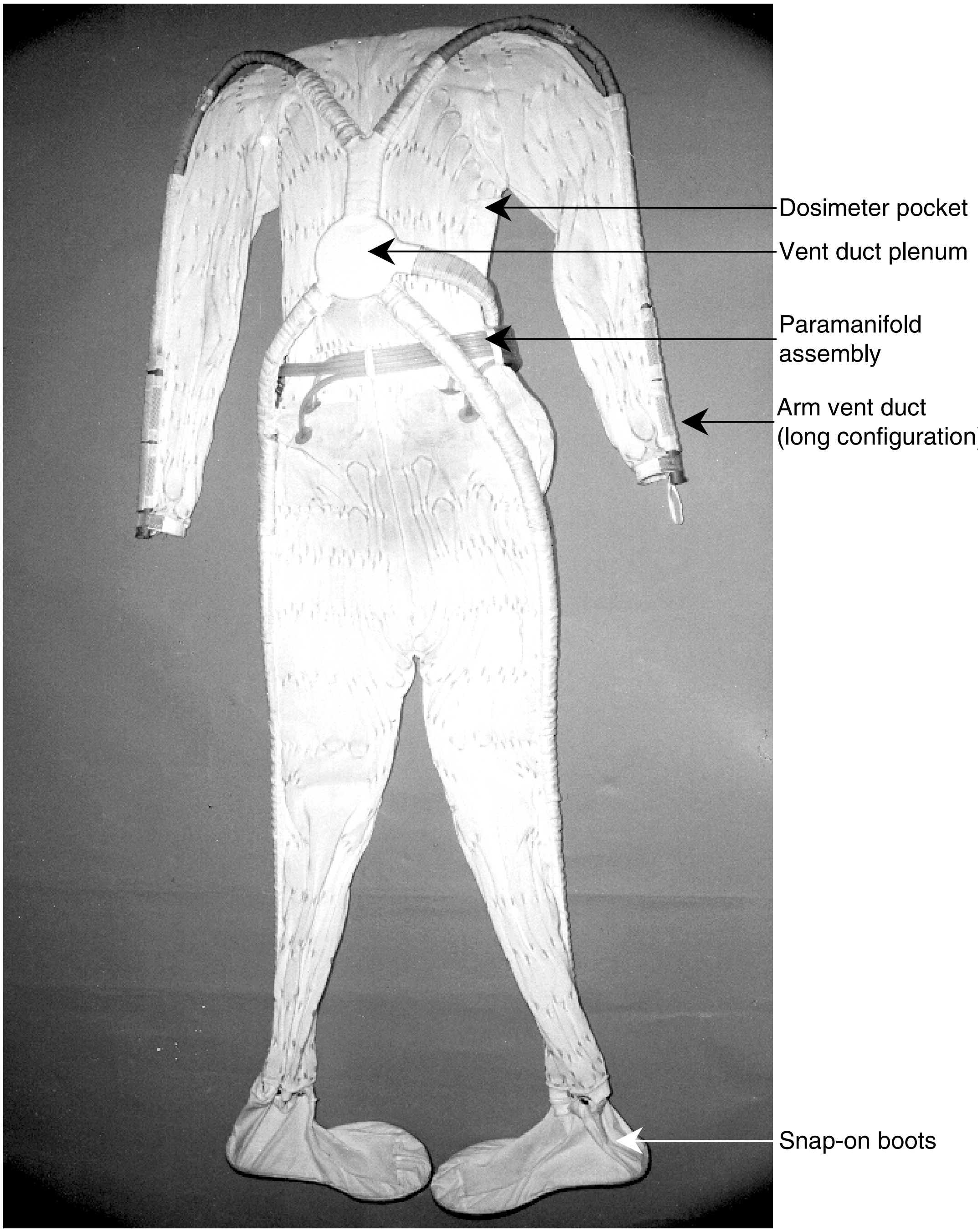

Figure 2-44. LCVG, back view

The garment includes a network of flexible tubing that circulates water over the body to provide cooling to the crewmember. The LCVG holds approximately 0.5 to 0.75 lb of water. The water is cooled by the PLSS (sublimator) during EVA operations and by the orbiter heat exchanger during Intravehicular (IV) ops. Ducts in the garment pick up the suit ventilation gasses at the body extremities. The gasses then flow back to the PLSS to complete the suit

ventilation loop. Both the ventilation and cooling loops are connected from the LCVG to the HUT at the multiple water connector.

The LCVG is sized to fit the crewmember based on a sizing system with seven size ranges. The sizing system is as follows:

a. The restraint/liner fits the 5th percentile female to the 95th percentile male.

b. During ground processing, the vent ducts can be shortened or lengthened at the shoulders and hips, and there are two configurations for the arm ducts. One configuration of the arm vent ducts reaches the wrist. A shortened configuration is available that terminates above the elbow.

c. Seven integrated boot sizes fit most female and male shoe sizes.

d. Snap-in leg extension cuffs are available to lengthen the garment legs.

The outer restraint fabric of the LCVG is made from a nylon/spandex mesh to allow for the weave-through of the water tubing (Figure 2-43). The nylon/spandex mesh holds the tubing firmly against the crewmember's body. Entry into the LCVG is through a full-torso-length zipper (Figure 2-43).

An inner lightweight liner assembly made of a nylon/tricot material is sewn to the restraint to aid in the donning and doffing of the LCVG to prevent the tubes from being snagged.

The LCVG boot is a soft, flexible slip-on assembly that fits snugly over the foot. The boot (Figure 2-44) is attached to the restraint assembly or an optional leg cuff via snaps. White cotton socks typically are worn under the LCVG boots.

Crew optional pads can be sewn to the outer restraint fabric to provide a comfortable fit. These pads are discussed in Section 5.1.

The biomed pocket is a small open pocket located on the left front side of the restraint assembly that contains the biomed signal conditioner box (Figure 2-43). A corresponding hole exists in the restraint and liner to allow for the biomed sensors to pass through to the crewmember's body.

Another pocket is provided under the crewmember's right arm for the placement of a passive dosimeter (Figure 2-43). The EVA crewmember transfers the dosimeter from his in-flight garments to the LCVG before donning the garment.

Chilled water removes excess metabolic heat as it circulates around the crewmember's body through a network of clear flexible tubing. The approximately 275 ft of tubing is made of ethyl vinyl acetate because it leaches the least amount of impurities into the PLSS. The tubing network begins and ends at the interface of the paramanifold tubing and the MWC. The paramanifold assembly is made of two inlet/outlet fittings and eight 5/16-inch-diameter tubes bonded side by side. At each arm and each leg, two of these eight tubes bond to a tee fitting.

The 4 tee fittings each divert the water into 12 different circuits of 1/8-inch-diameter garment tubing.

Ventilation gasses enter the vent duct system at the crewmember's extremities. The gasses are carried away through the arm and leg duct assemblies to the vent plenum assembly located in the middle of the crewmember's back (Figure 2-44). From the vent plenum assembly, the gases are channeled into the torso vent duct for return to the HUT/PLSS via the LCVG multiple water connector.

As described on the previous page, the arm vent ducts are available in long and short configurations. The long configuration reaches the wrist (Figure 2-44), where optional wristlets can be worn to prevent the ducts from rubbing against the wrists (Figure 5-4). These wristlets are elastic bands modified from white cotton athletic socks. The short configuration ends at the elbow because some crewmembers do not have enough clearance inside the lower arm assembly to wear the long vent duct (Figure 2-43). This creates crewmember discomfort in the forearm and eventual fatigue. For both vent duct configurations, the end of the LCVG sleeve has a thumb loop that prevents the LCVG sleeves from riding up the arm and getting caught in the arm bladder during HUT donning.

The LCVG multiple water connector is the passive half of the MWC (Figure 2-45). It consists of inlet and outlet fittings for the paramanifold assembly, a fitting for the torso vent duct, and a connector that mates with the multiple connector on the HUT. When the MWC halves are locked together, cooling water flows in and out of the LCVG and ventilation gas returns to the PLSS.

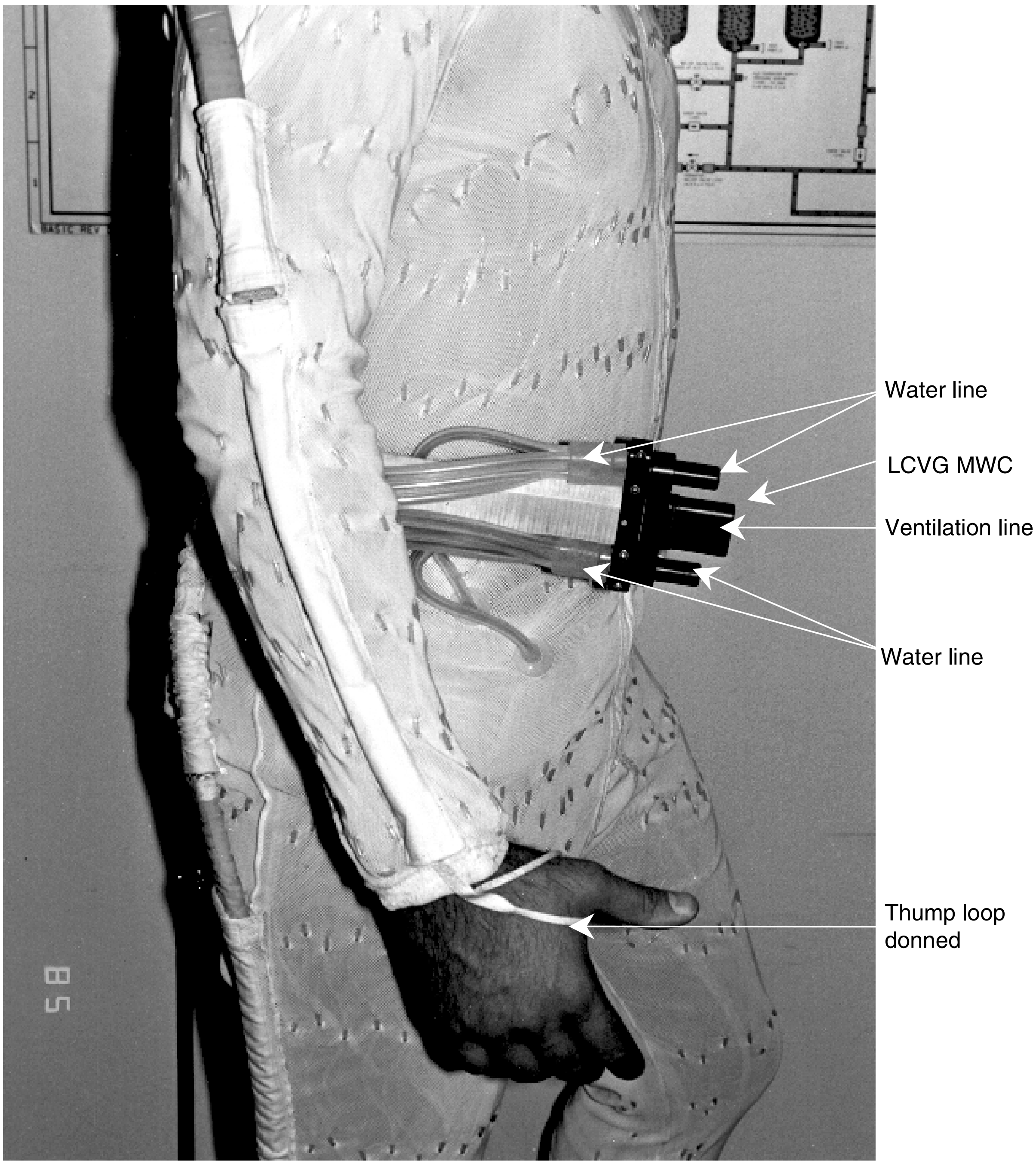

Figure 2-45. Thumb loop and MWC–LCVG (passive) half

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The HUT multiple water connector is the active half of the MWC and contains the locking mechanisms (Figure 2-46). The primary mechanism is a stainless steel sliding plate with a thumb lock button. There is also a secondary safety lock. To lock the connector, press the two halves together and the primary lock will latch. Then engage the safety lock by sliding it to the crewmember's left. To unlock the connector, first slide the safety lock to the right. Then undo the primary lock by sliding the thumb lock button downward and to the right to engage the sliding plate. This two-motion action must be performed while pressing the two halves of the MWC together. To ensure no water leakage out of the LCVG when not connected to the HUT, an MWC jumper is installed as an end cap. This is removed prior to mating the LCVG to the HUT.

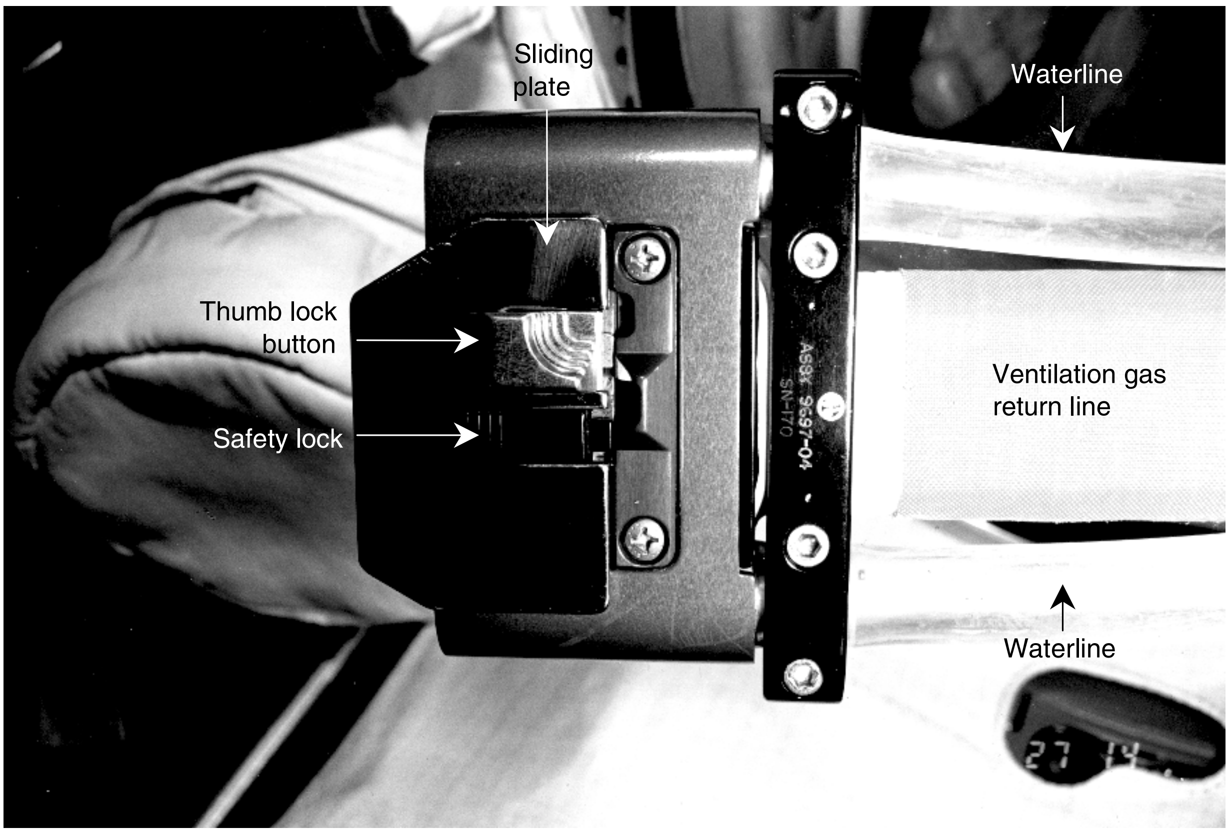

Figure 2-46. MWC–HUT (active) half

2.7 Operational Bioinstrumentation System

The biomed system acquires the crewmember's ECG signal and sends the signal to the EMU radio for downlink to Mission Control. It includes the following components (Figure 2-47):

a. Sternal harness

b. Bio kit

c. Signal conditioner

d. EVA cable (pigtail adapter)

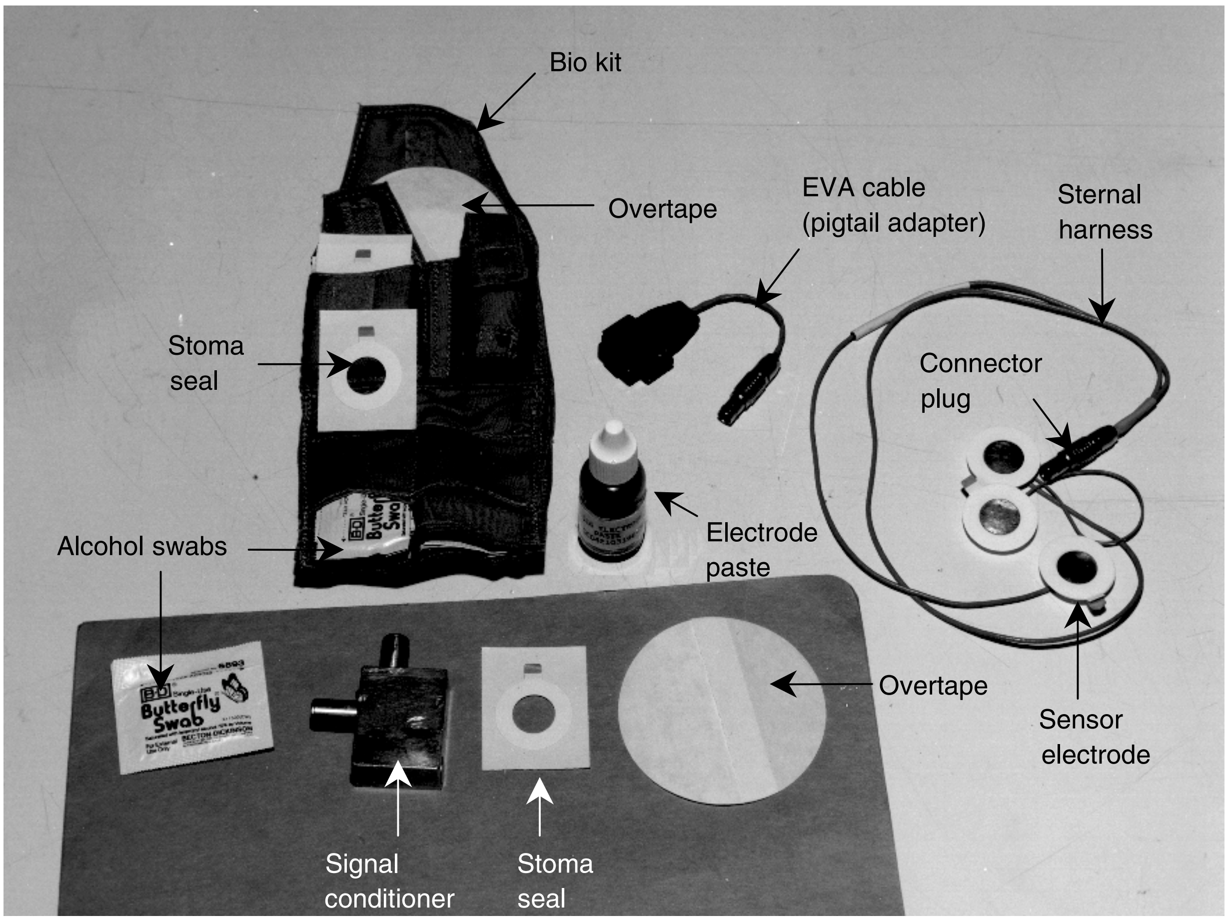

Figure 2-47. Operational bioinstrumentation system

The sternal harness contains three sensor electrodes, two wires, and a connector plug. The three electrodes adhere to the crewmember's chest and acquire the ECG signal. The upper chest and ground electrodes are attached to one wire, and the lower chest electrode is attached

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to the other wire. Both wires attach to the connector plug, and the plug mates to the signal conditioner.

The bio kit contains the following: stoma seals, electrode paste, alcohol swabs, adhesive overtapes, and an electrode placement diagram. The electrode placement diagram in the EVA checklist shows the proper positioning of the electrodes on the crewmember's chest. The stoma seals are double-sided, doughnut-shaped adhesives. One side sticks to the plastic border on the electrode; the other side sticks to the skin. Electrode paste is placed on the electrodes to help adhere them to the crewmember's chest and provide a good electrical connection between the skin and the electrodes. Alcohol swabs clean the places on the skin to which the electrodes adhere. After the electrodes are stuck to the skin, the 3-inch-diameter adhesive overtapes stick over the electrode onto the skin to provide redundancy.

The signal conditioner houses input and output connectors and a battery. Before launch, the signal conditioner is placed in the biomed pocket; the sternal harness is routed in the LCVG; and the sternal harness connector plug is mated to the input connector. The ECG signals come into the input connector through the sternal harness connector plug. The signal conditioner battery activates when the EVA cable is mated to the output connector. The conditioner is tuned preflight to the individual crewmember.

The EVA cable, or "pigtail adapter," connects the biomed signal conditioner to the EMU electrical harness. The crewmember attaches the pigtail adapter to the signal conditioner after donning the LCVG. The other end of the pigtail is connected to the EEH after the crewmember dons the LTA and HUT prior to waist ring engagement. When this is all connected and the comm system is properly configured, the ECG signal is picked up at the electrodes, carried through the signal conditioner and the EEH to the SSER, then transmitted to the orbiter for downlink.

2.8 Communications Carrier Assembly

The CCA, or “comm cap,” is a cloth aviator-type cap that positions the microphones and earphones necessary for EVA communication (Figure 2-48). It allows EVA crewmembers to talk to each other, to the orbiter, and to MCC via the orbiter communications system. It also allows the crewmembers to receive EMU caution and warning tones. There are five sizes that allow it to fit crewmembers who are in the 5th to 95th percentile.

The CCA includes the following components:

a. Skull cap

b. Neck strap

c. Crew-optional chin strap

d. Crew-optional perspiration absorption strap

e. Earcups

f. Microphone modules

g. Earphones modules

h. Microphone booms

i. Summing module

j. Ear seals

k. Interconnect wiring

l. Interface cable and connector

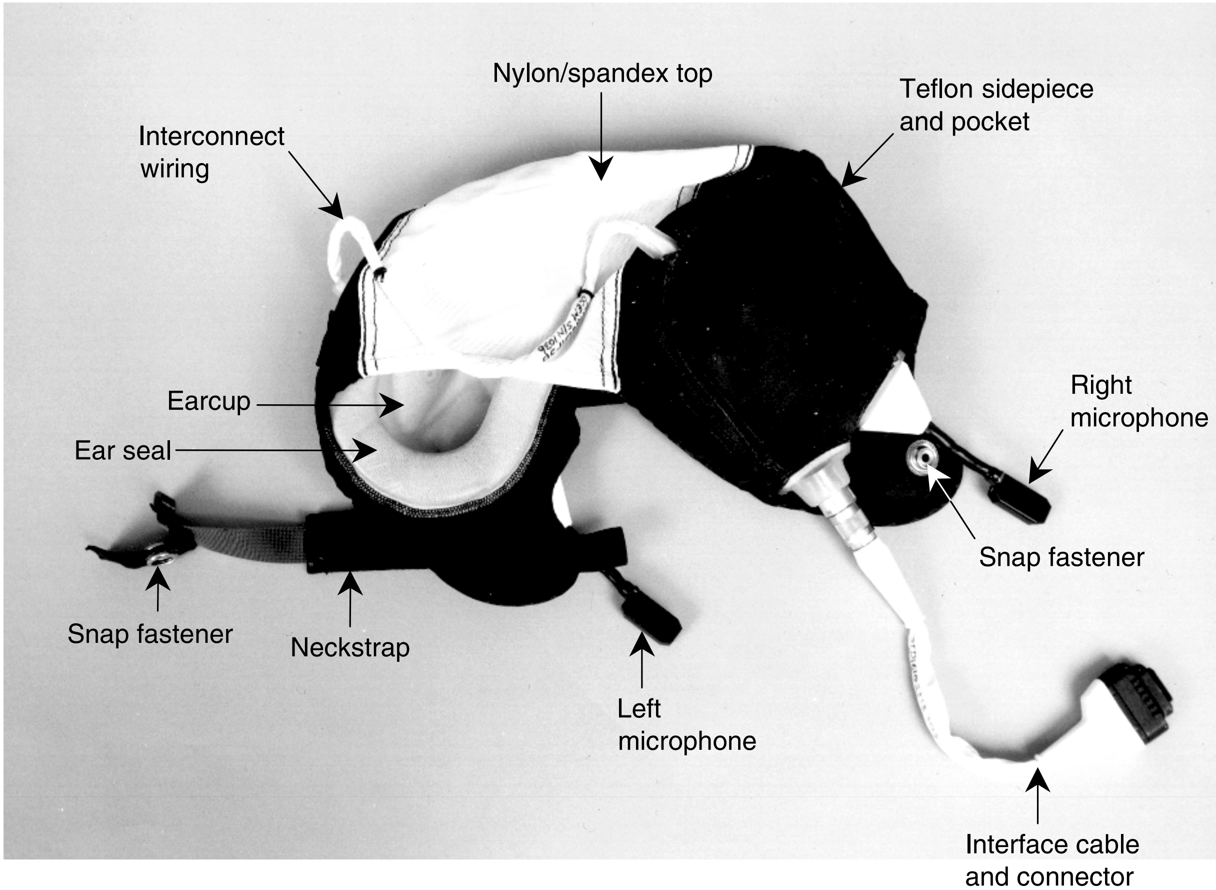

Figure 2-48. CCA

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The skull cap forms the main body of the CCA. It is made of two Teflon sidepieces with pockets for the communication electronics (Figure 2-49). The two sidepieces are joined by nylon/spandex cloth. The pockets house the earcups with the earphone modules, microphone modules, and amplifiers molded in a single unit. Nylon zippers along the tops of the pockets allow ground servicing of the earcups. Teflon/Velcro tabs cover the ends of the zippers to prevent them from scratching the helmet.

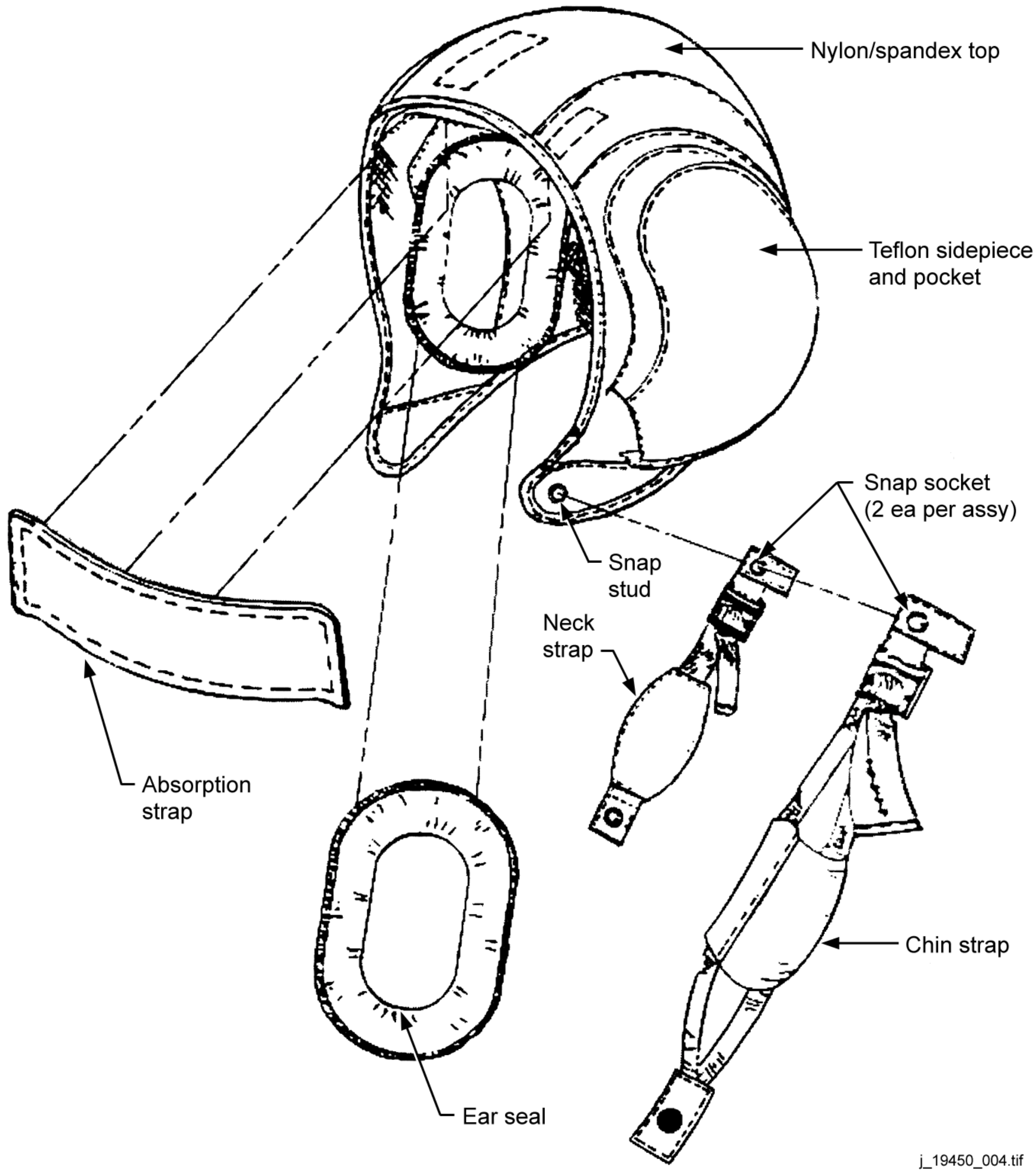

Figure 2-49. CCA without electronics

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A neck strap or a crew-optional chin strap is used to hold the CCA in place (Figure 2-50). The strap is 5/8-inch nylon webbing. Two “lift-the-dot” snap fasteners attach the strap to the skull cap. A buckle is used to adjust the fit.

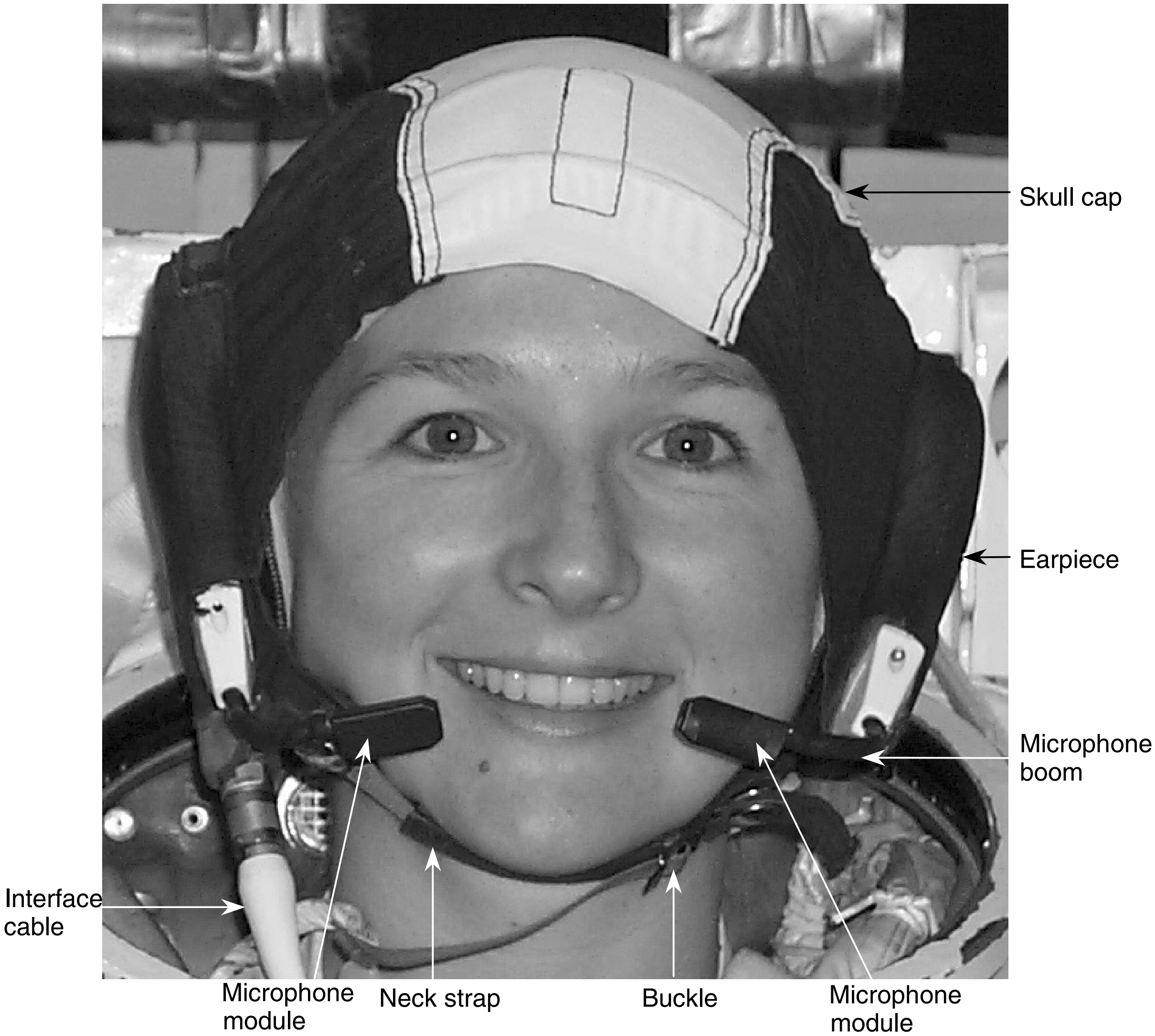

Figure 2-50. CCA donned

The perspiration absorption strap is a crew option. It is made of 1/8-inch urethane foam with a 1/8-inch Teflon felt backing. It is attached to the front edge of the skull cap with Velcro, and its presence or absence does not affect the fit of the CCA.

The molded silicone earcups contain the CCA electronics (Figure 2-51). Each earcup houses an independent microphone module and earphone module; the right earcup also houses a summing module. The microphone and earphone modules are redundant, so if the right earphone module fails, the crewmember can hear with the left earphone module. A microphone boom extends from each microphone module and should be adjusted to place the microphones near the corners of the mouth. The microphones are designed to work optimally during EVA at 4.3 psi and can be very noisy at higher pressures, such as 10.2 psi or 14.7 psi. The earphones produce both the voice and caution/warning tones.

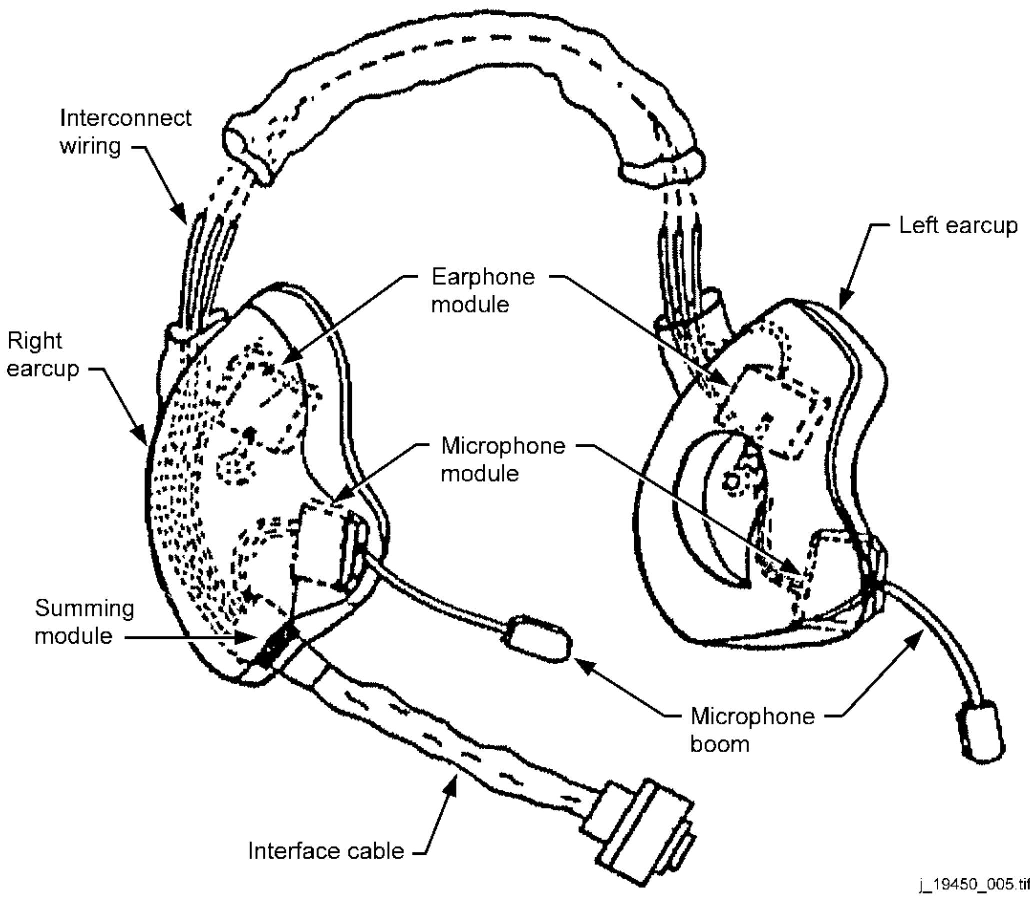

Figure 2-51. CCA electronics

The ear seals are Velcroed to the skull cap around the earcups. They are doughnut shaped and constructed of latex foam with a deerskin cover. These seals channel the communication signals directly into the crewmember's ear and help block interfering suit noise.

The interconnect wiring wraps around the outside rear of the CCA and joins all the electronics at the summing module. The interface cable and connector come from the summing module and mate to the EEH.

2.9 In-Suit Drink Bag

The IDB supplies drinking water to the crewmember during EVA (Figure 2-52). It is a bag assembly that is attached to the interior of the HUT. The IDB is available in two sizes, 21 ounces and 32 ounces.

The IDB includes the following components:

a. Bladder

b. Velcro attachments

c. Outlet (drink) valve

d. Drink tube

e. Inlet valve

f. IDB fill tool

g. IDB syringe

h. Red-red hose

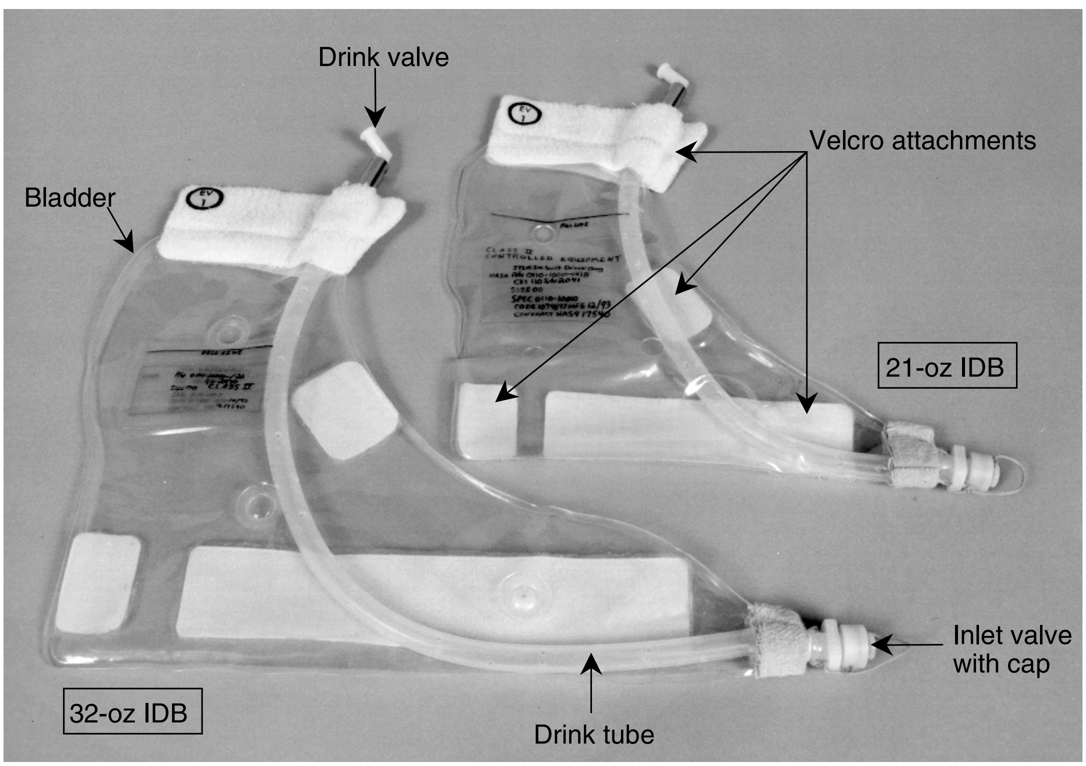

Figure 2-52. IDB

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The bladder assembly is made of polyurethane film. The two halves of the bladder are joined by dielectric heat seals (Figure 2-53). Circular heat seals (known as "dots") are placed at four locations on the bladder. These dots join the front and back bag surfaces to keep the bag from ballooning.

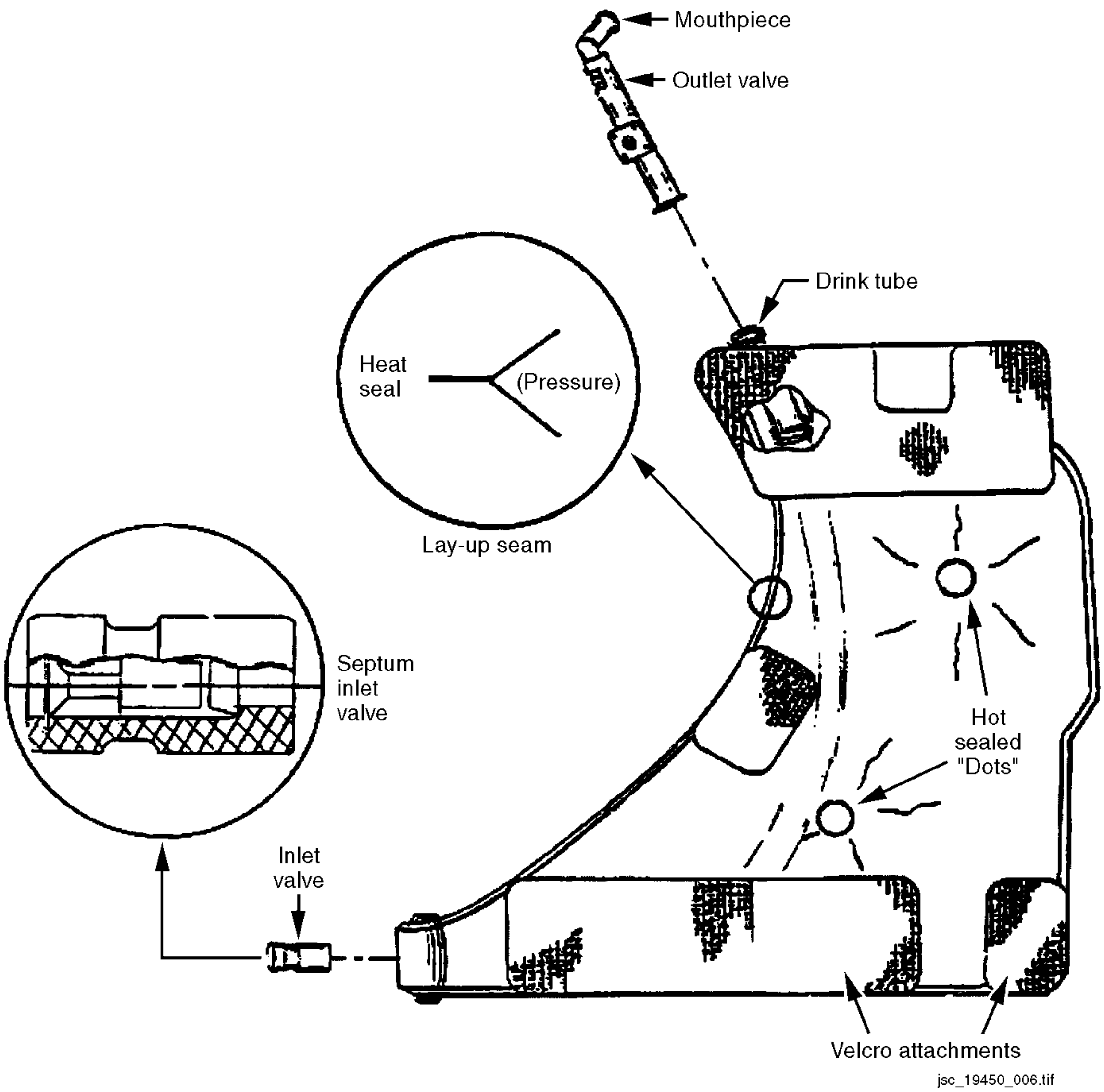

Figure 2-53. IDB drawing

Velcro is bonded to the bladder so that the bag can attach to the inside front of the HUT (Figure 2-52). Within the range of the Velcro, the position of the drink valve can be adjusted so that it is in reach of the lower right corner of the mouth. Velcro tabs also are on the HUT near the bottom fill valve of the bag. These mate around the bottom of the bag to keep it from being dislodged while donning the HUT.

Sucking on the drink valve mouthpiece unseats a spring-loaded valve poppet from an O-ring, allowing water to flow from the bladder. The valve requires a pressure differential of 0.15 psid for water to flow. When not drinking, the poppet closes against the O-ring to stop water flow.

The drink tube extends to the bottom of the drink bag, has small holes at 1-inch intervals along its length, and has a 45° cut at the bottom. This combination ensures proper water flow regardless of orientation.

The bag is filled with water from the orbiter galley through the inlet valve at the bottom of the bag. This is done by connecting the red-red hose to the galley and to the IDB fill tool, then inserting the IDB fill tool into the inlet valve. The red-red hose is stored in the In-Flight Maintenance (IFM) hose kit. The IDB fill tool has a syringe on the end, which is inserted into the IDB, and a switch to control water flow.

After filling, the IDB syringe is used to degas the bladder (Figure 2-54). First the bag is spun slightly while holding the inlet valve. This separates the gas and the water. Next the syringe is inserted into the IDB inlet valve and the gas is drawn out. Degassing must be done; otherwise, the gas expands in the IDB as the pressure in the EMU decreases and potentially can cause the IDB to rupture.

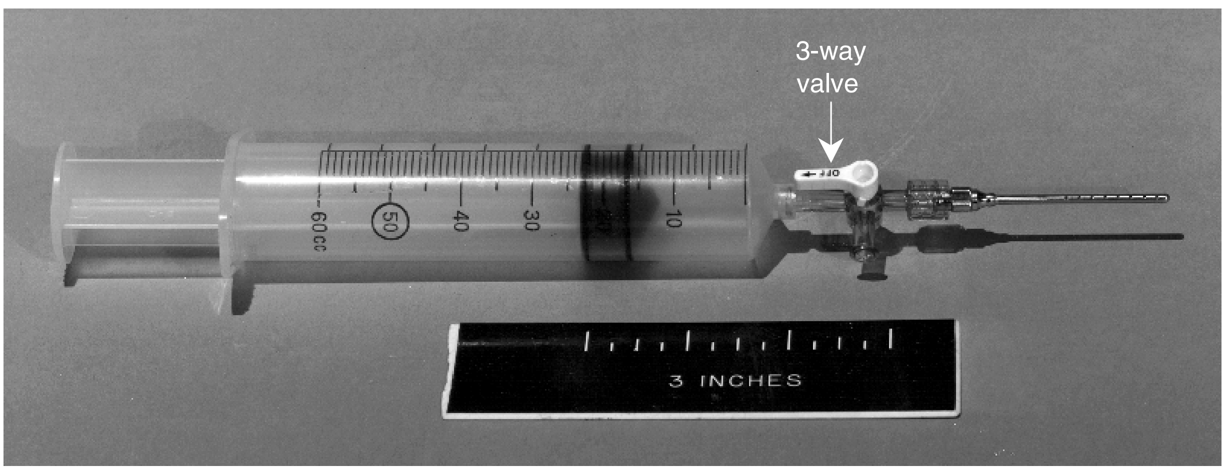

Figure 2-54. Degassing syringe

A Disposable In-Suit Drink Bag (DIDB) is currently being developed.

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2.10 Maximum Absorbency Garment III

The MAG III consists of multiple layers of material designed to rapidly absorb and store urine (Figure 2-55).

The MAG includes the following components:

a. Top and bottom layers of absorbent material

b. Fitted elastic brief

c. Adhesive tape

Figure 2-55. MAG

While they are in the EMU, male and female crewmembers wear the MAG under the LCVG to absorb urine. The brief is secured on the crewmember with adhesive tape. The absorbent layers in the brief have the capacity to absorb 950 ml of urine; it is disposable after one use. The MAG is made of adult undergarment materials that are available commercially.

2.11 Urine Collection Device

The UCD is a disposable, flexible container that has the capacity to hold up to 32 fluid ounces of urine (Figure 2-56). It is not often used because most crewmembers prefer to use the MAG.

The UCD includes the following components:

a. Collection bag

b. Attachment straps (with Velcro fasteners)

c. One-way check valve

d. Disposable roll-on cuff

e. Disposal clamp

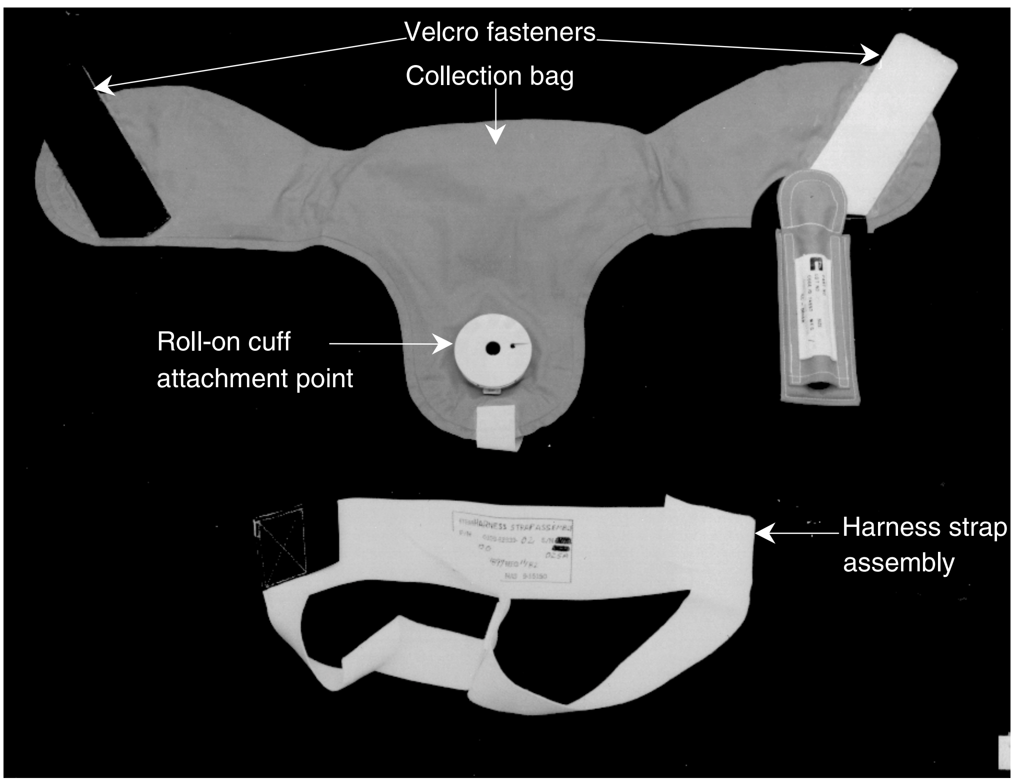

Figure 2-56. UCD

The UCD is worn under the LCVG by male crewmembers during EVA. It is designed for one-time use and is then disposed of as wet trash. The collection bag is fabricated of urethane-coated nylon and incorporates a one-way check valve for urine passage. A disposable roll-on cuff is used at the crewmember interface. After EVA, a disposal clamp is attached to prevent urine from escaping from the containment bag when in wet trash.

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Section 3
Life Support Subsystem

The Life Support System (LSS) provides a habitable environment inside the EMU. This section describes the specific functions, components, specifications, and operations of the LSS. Each of the subsystems is also discussed.

The LSS performs the following functions:

a. Supplies oxygen.

b. Pressurizes and ventilates the EMU.

c. Allows the crewmember to communicate.

d. Purifies breathing gas.

e. Keeps the crewmember at a comfortable temperature.

f. Provides electrical power.

g. Provides a servicing interface.

h. Displays EMU parameters to crewmembers.

i. Allows the crewmember to control EMU functions.

j. Monitors EMU consumables and operational integrity.

The LSS includes the following components:

a. Primary Life Support Subsystem (PLSS)

b. Secondary Oxygen Pack (SOP)

c. Space-to-Space EMU Radio (SSER)

d. Display and Control Module (DCM)

e. Caution and Warning System (CWS)

f. Contaminant Control Cartridge (CCC)

g. EMU electrical system

The PLSS makes up the main part of the EMU backpack. The SOP is a separate unit attached to the bottom of the PLSS. The SSER, the CWS, and the CCC fit inside the PLSS but are considered separately. The DCM attaches to the front of the hard upper torso at chest level. The EMU electrical system includes components located in many parts of the EMU.

3.1 Primary Life Support System

The PLSS, Item 100 (I100), makes up the largest portion of the LSS (Figures 3-1 to 3-3). It is helpful to refer to Space Shuttle Systems Handbook (SSSH) Drawing 21.10 while reading about the PLSS. The functions of the PLSS (Figure 3-1) are to provide the following:

h. Oxygen for breathing

i. Thermal control

j. Suit pressurization

k. Purification of breathing gases

The PLSS consists of the following:

a. Primary oxygen system

b. Oxygen ventilation circuit

c. Liquid transport system

d. Feedwater circuit

The maximum weight of the PLSS when charged with oxygen and water is 102.7 lb.

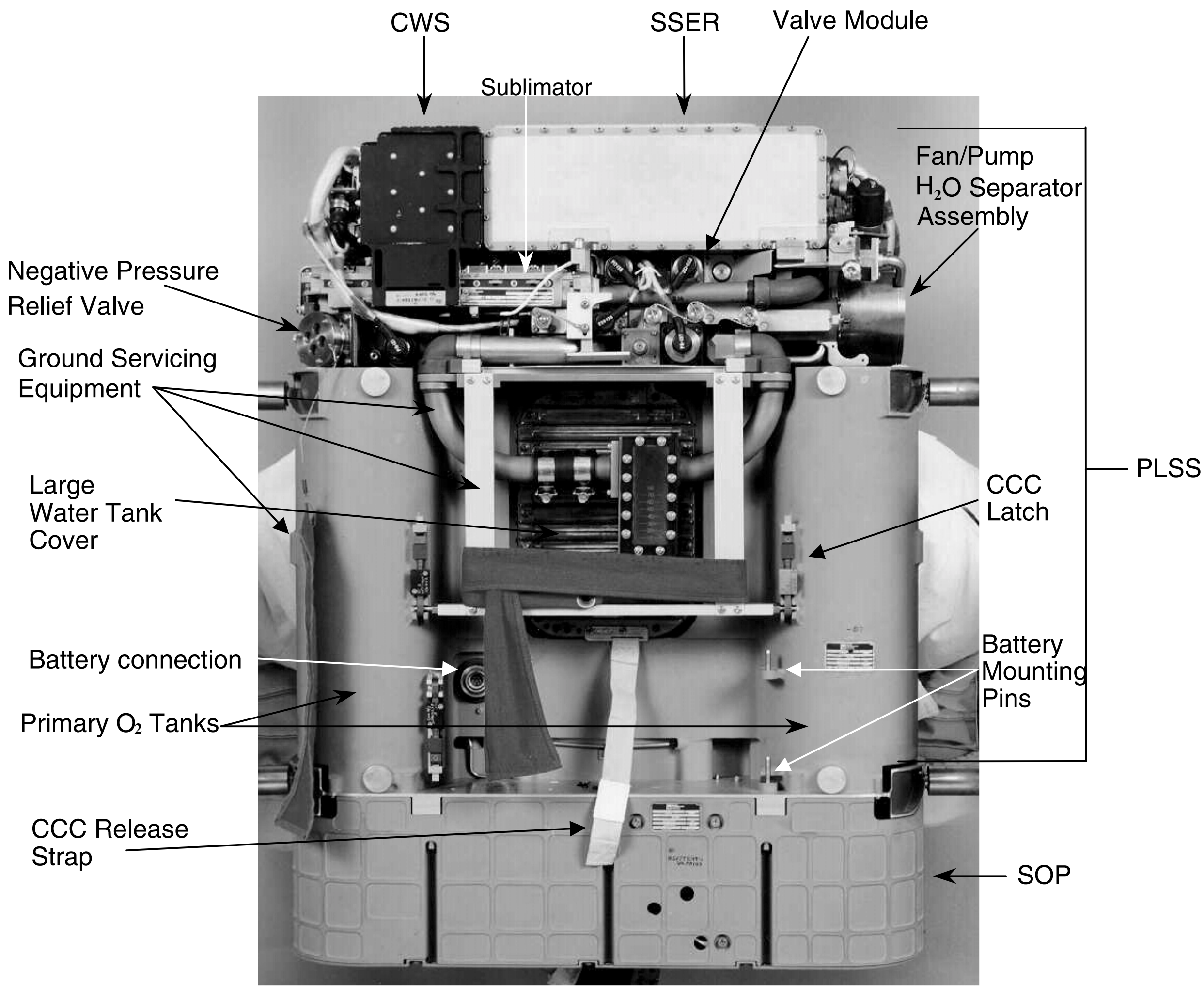

Figure 3-1. LSS, back view without TMG

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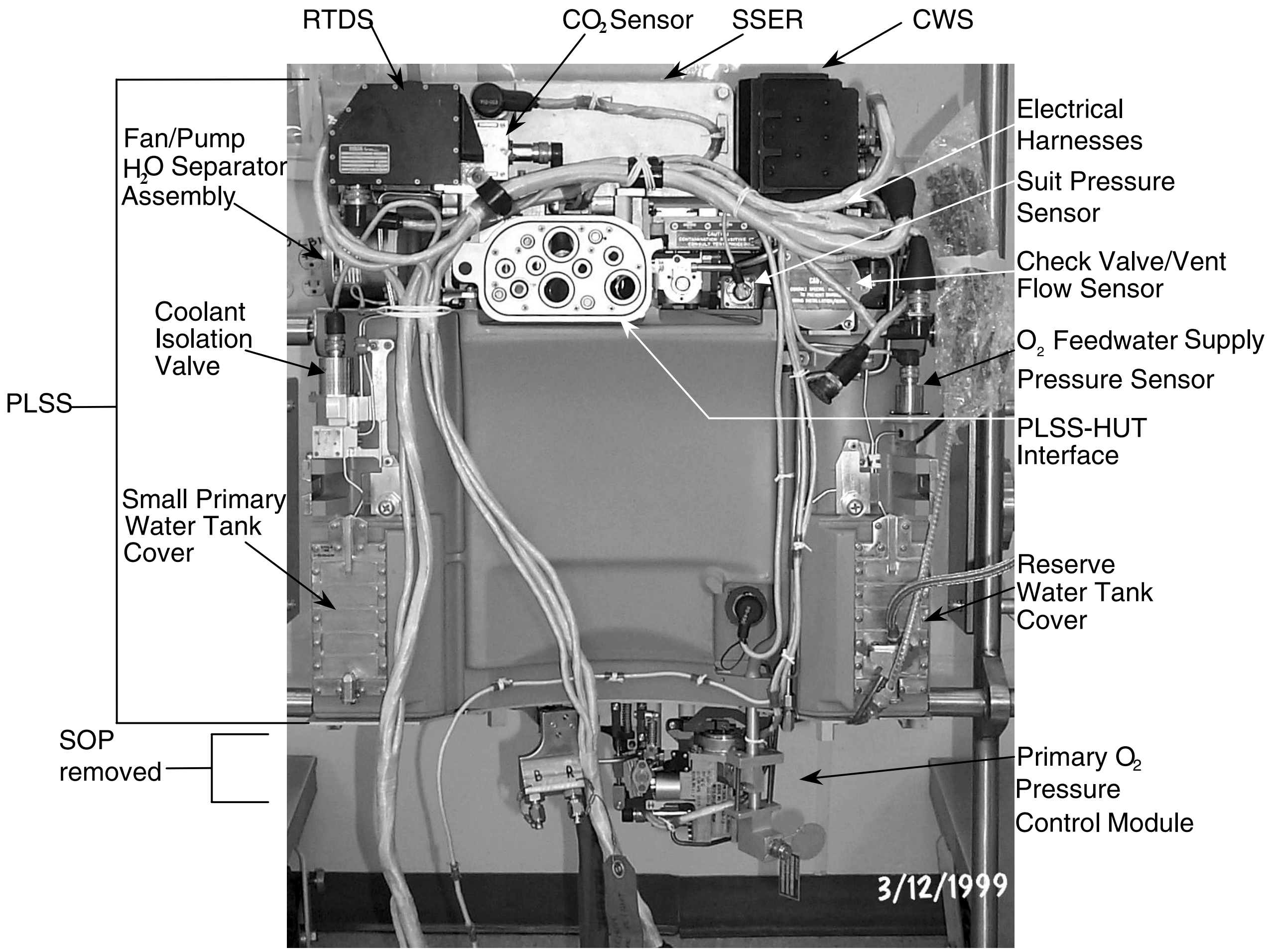

Figure 3-2. PLSS, front view without TMG, HUT, or SOP

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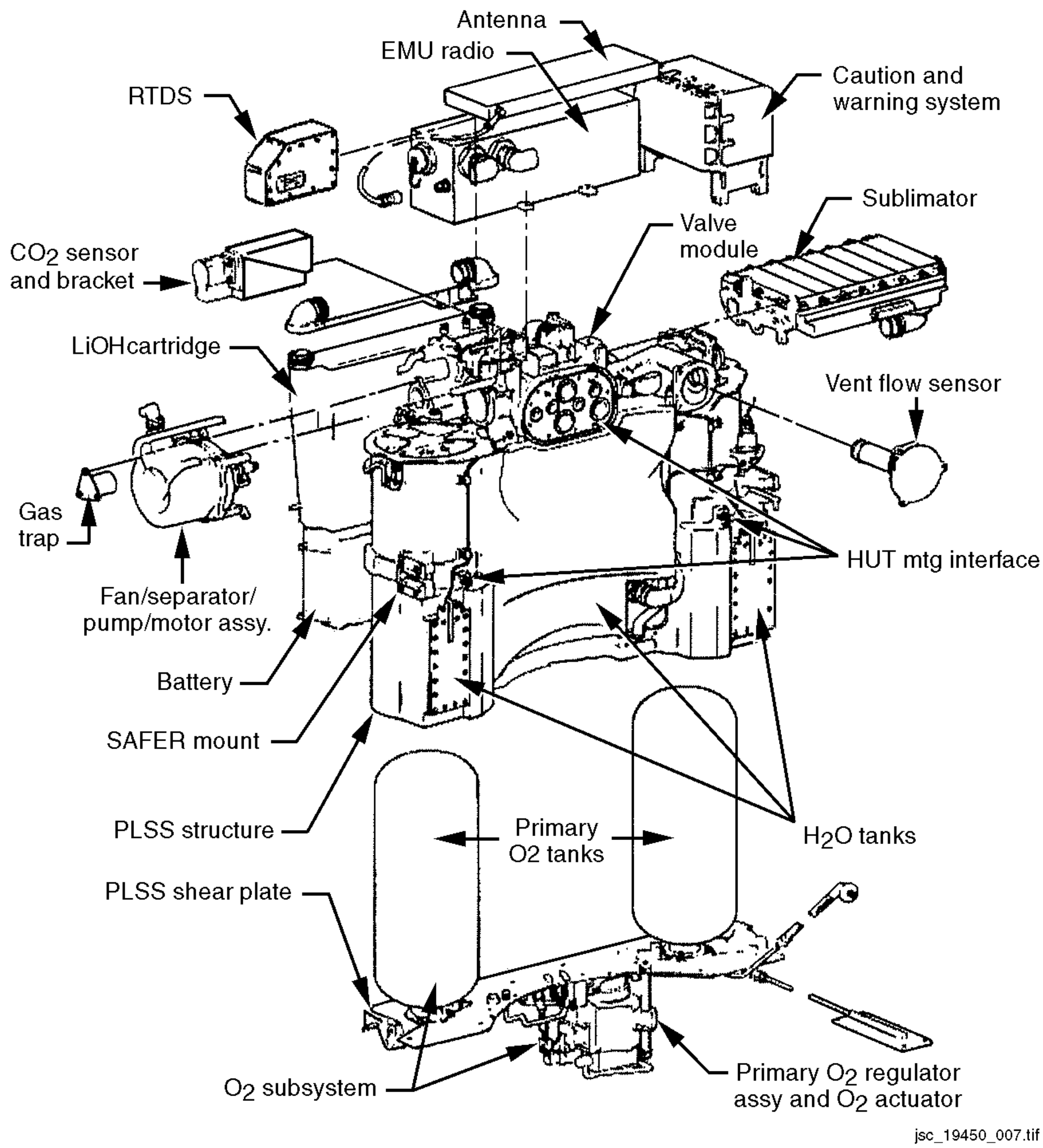

Figure 3-3. PLSS component arrangement

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3.1.1 Primary Oxygen System

The primary oxygen system performs the following functions:

a. Suit pressurization

b. Oxygen for breathing provided

c. Feedwater pressurization

The system includes the following components:

a. O_2 tanks (two) (I111)

b. O_2 tank pressure sensor (I112)

c. Flow limiter (I113B)

d. O_2 shutoff valve (I113C)

e. Suit pressure regulator (I113D)

f. Sense lines

g. O_2 actuator (I115)

h. Filters

i. Check valves (two) (I113A and I120C)

j. H_2O pressure regulator (I113E)

k. Dual mode relief valve (I120B): High mode and low mode

l. Bleed orifice (I120A)

m. Oxygen feedwater supply pressure sensor (I132A)

n. Test ports (two)

The specifications for the primary oxygen system are listed in Table 3-1.

Table 3-1. Primary oxygen system specifications

Item	Parameter	Specification
System	Design EVA time	7 hr
	Nominal suit pressure during EVA	4.3 ± 0.1 psid
Tanks (2)	Minimum usable system oxygen quantity (with both tanks)	1.217 lb at 850 psia and 90° F
	Volume per tank	240 in^3
	Normal operating pressure/ Normal fill pressure on orbit	900 ± 50 psia
	Maximum operating pressure	1050 psia
	Proof pressure (1.5x max. operating)	1575 psia
	Burst pressure (2x max. operating)	2100 psia
O_2 pressure sensor	Measurable pressure range	0 to 1100 psia
	Normal pressure measured	100 psia to 900 psia
	Accuracy	±2.5 percent F.S. (±27.5 psi)
Flow limiter	Maximum flow rate	7.49 lb/hr @ 1050 psia
O_2 shutoff valve	Maximum leak rate (with valve closed)	6 scc/hr
Suit pressure regulator	Minimum system operating pressure	75 psia
	Regulated suit pressure EVA/PRESS mode IVA mode	 4.3 ± 0.1 psid 0.9 ± 0.5 psid
	Controllable flow rate	0.02 to 0.33 lb/hr (0.21 to 3.48 psi/min)
H_2O pressure regulator	Feedwater tank regulated pressure	15.15 ± 0.55 psid
High mode relief valve	Cracking/reseat pressure	16.25 to 17.8 psid above ambient
	Flow	7.5 lb/hr O_2 minimum
Low mode relief valve	Cracking pressure	0.26 to 0.80 psid
	Opening pressure	1.0 psid between H2O regulator supply pressure and H2O tank gas pressure
	Flow	450 scc/min minimum
Bleed orifice	Flow	83-145 scc/min O_2
O_2 feedwater supply pressure sensor	Measurable pressure range	0 to 40 psia
	Accuracy	±2.5 percent F.S. (±1 psi)

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The system is designed to provide sufficient oxygen for a 6-hour EVA, 15 minutes of egress, 15 minutes of ingress, and 30 minutes of reserve. The orbiter Environmental Control and Life Support System (ECLSS) recharges the primary O_2 system on orbit through the Service and Cooling Umbilical (SCU).

The two oxygen tanks are critical pressure vessels, which means that any defects will cause leaks before the tanks lose structural integrity and burst. The O_2 pressure sensor, a pressure transducer, is located between the oxygen tanks and the manual shutoff valve to measure the primary oxygen tank pressure. The CWS uses this pressure measurement and displays it to the crewmember on the DCM.

A flow limiter is located downstream of the O_2 pressure sensor and upstream of the O_2 shutoff valve. The flow limiter prevents the O_2 flow rate from exceeding 7.49 lb/hr in case the suit pressure regulator fails open. This flow rate is lower than the rate at which the positive pressure relief valve in the ventilation loop can vent to ambient. Therefore, this flow limiter protects the EMU from overpressurization by the primary oxygen system.

The O_2 shutoff valve and the suit pressure regulator work together to control suit pressure, and both are controlled by an O_2 actuator on the DCM (Figure 3-4). These control combinations are described in Table 3-2.

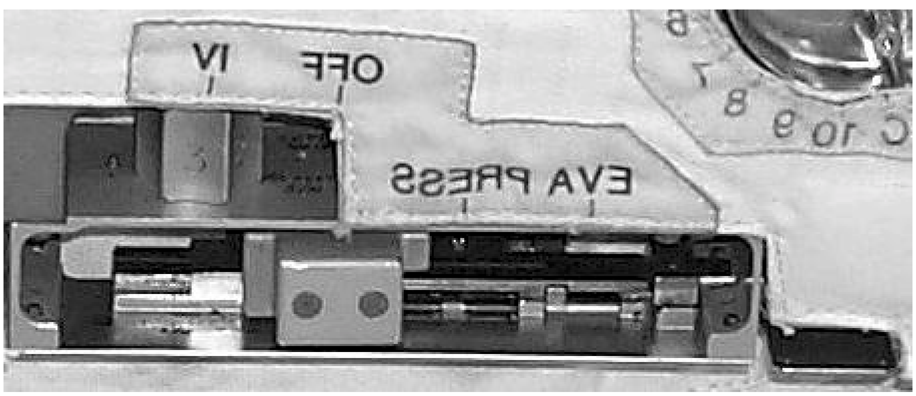

Figure 3-4. O_2 actuator on the DCM

Table 3-2. Primary oxygen system control settings

	O_2 actuator OFF	**O_2 actuator IV**	**O_2 actuator PRESS**	**O_2 actuator EVA**
O_2 shutoff valve position	Closed	Open	Open	Open
Suit pressure regulator setting	4.3 ± 0.1 psid	0.9 ± 0.5 psid	4.3 ± 0.1 psid	4.3 ± 0.1 psid
Flow to water pressure regulator	No	Yes	Yes	Yes
SOP enabled	No	No	No	Yes

The SOP ties into the primary oxygen system downstream of the suit pressure regulator. Both systems then connect to the oxygen ventilation circuit.

The water pressure regulator is located downstream of the oxygen shutoff valve, on a different branch of the loop than the suit pressure regulator. When the oxygen shutoff valve is open, the water pressure regulator automatically regulates feedwater pressure so that any gas dissolved in the water stays in solution when EVA.

Pressure sense lines are located downstream of both the water pressure and suit pressure regulators. The sense lines provide the regulators the downstream pressures and cause them to open or close to maintain pressure. A compensator line upstream of the suit pressure regulator improves regulator accuracy by providing the upstream pressure to that regulator.

Past the water pressure regulator, the loop branches again. One branch leads to Test Port F (TPF), used for ground processing and Bends Treatment Adapter (BTA) operations (Section 4.11). The other branch leads to a check valve, which prevents any moisture-laden gas in the water tanks from backflowing into the rest of the system and causing corrosion.

Downstream of the check valve are the feedwater tanks, a bleed orifice, and the dual mode relief valve. The line leading to the feedwater tanks allows the tanks to be pressurized with oxygen. The bleed orifice allows a small amount of oxygen to flow into the suit. This places a constant demand on the water pressure regulator to prevent it from deadheading. The flow it allows is less than that required for the EMU's minimum metabolic rate of 400 Btu/hr. This prevents the orifice from causing suit overpressurization.

The dual mode relief valve consists of low mode and high mode relief valves. The low mode relief valve allows the water tanks to be filled quickly by venting the pressure on the tanks to the HUT. The high mode relief valve prevents the water tanks from being overpressurized if the water pressure regulator fails open.

Operation of the low mode relief valve is as follows: Two pressure sense lines monitor pressure on each side of the check valve. When the oxygen shutoff valve is closed after the EMU has been pressurized, a pressure differential develops across the check valve. This happens because the lines upstream of the check valve bleed into the EMU more rapidly than the lines downstream of the valve, which are flow-limited by the orifice. When a pressure differential greater than 1 psi develops across the check valve, the low mode relief valve then opens, bypassing the orifice, and relieves pressure from the line and the water tank cavities into the HUT.

The high mode relief valve opens when there exists a pressure differential of at least 16 psid between the inlet of the valve and ambient. Like the low mode, the high mode bypasses the orifice and vents oxygen into the HUT. This prevents the pressure on the water tanks from exceeding 20 psia.

The primary oxygen tanks are filled through a charge fitting on the DCM when the SCU is connected and the airlock oxygen valves are open. A check valve between the DCM charge fitting and the oxygen tanks is designed to prevent backflow if the supply pressure drops below the oxygen tank pressure. The check valve also is redundant to the DCM charge fitting to prevent oxygen leakage through the fill line.

Filters are included in the primary oxygen system to protect the crewmember and hardware from failures caused by debris in the system.

3.1.2 Oxygen Ventilation Circuit

The oxygen ventilation circuit performs the following functions:

a. O_2 circulation

b. Removal of CO_2, humidity, and trace contaminants

c. Cooling of ventilation gas

d. Prevention of helmet fogging

The system includes the following components:

a. Suit pressure sensor (I114)

b. Suit pressure gauge (I311)

c. Flow limiter (I126)

d. CO_2 sensor (I122)

e. CCC (I480)

f. Fan/water separator (I123A & B)

g. Slurper/sublimator (I140)

h. Vent flow sensor/backflow check valve (I121)

i. Helmet purge valve (a.k.a. Combination Purge Valve (CPV)) (I105B)

j. DCM purge valve (I314)

k. Positive pressure relief valve (I146)

l. Negative pressure relief valve (I147)

m. SOP checkout package (I145) (functionally replaced by the SCOF; see below)

n. SOP Checkout Fixture (SCOF) (Section 4.12) (I495)

o. Filters

Table 3-3 lists the specifications for the oxygen ventilation circuit.

Table 3-3. Oxygen ventilation circuit specifications

Item	Parameter	Specification
Suit pressure sensor	Range	0 to 6 psid
	Accuracy	±2.5% F.S. (±0.15 psid)
Suit pressure gauge	Range	0 - 5.5 psid
	Accuracy	±0.1 psi from 3.0 to 5.0 psid
		±0.2 psi over rest of range
CO_2 sensor	Range	0.1 to 30 mmHg
	Maximum error	±2 mmHg CO_2
	Response time	15 sec. max.
	Nominal level measured	0.3 mmHg
	CWS alert level	3 mmHg
	CWS warning level	8 mmHg
Flow limiter	Flow	<1 percent of total vent flow
CCC	See Section 3.6	
Fan/water separator	Fan speed range	18,000 to 20,000 rpm
	Gas flow into helmet	6.0 ACFM minimum
Slurper/sublimator	Temp. of gas at outlet	Spec: 90° F max.
		Nominal: 50 to 60° F
	Dew point of gas at outlet	Spec: 65° F max.
		Nominal: 50 to 60° F
	Slurper holes	94
Vent flow sensor/ backflow check valve	Flow off indication	Flow <3.7 acfm O_2
	Flow on indication	5.7 acfm O_2 at 3.35 psia 5.4 acfm O_2 at 4.3 psia 5.1acfm O_2 at 14.7+ psia
	Backflow to close valve	3.0 lb/hr O_2 maximum
Helmet purge valve	Flow	2.5 ± 0.4 lb/hr at 3.35 psia
	Suit pressure, valve open	Not less than 3.33 to 3.9 psid
DCM purge valve	Flow	4.74 to 4.986 lb/hr O_2 at 3.45 psia
	Suit pressure, valve open	Not less than 3.33 to 3.9 psid

Table 3-3. Oxygen ventilation circuit specifications, continued

Item	Parameter	Specification
Positive pressure relief valve	Flow	7.79 lb/hr minimum dry O_2 at 5.5 psia suit pressure
	Cracking pressure	4.7 psid minimum
	Typical full open pressure	5.1 psid
	Reseat pressure	4.6 psid minimum
Negative pressure relief valve	Flow	32 lb/hr min. air at 4.15 psia ambient and 3.35 psia suit P
	Negative suit pressure	0.8 psid maximum at 4.15 to 14.7 psia
	Cracking/reseat pressure	0.2 psid minimum
SCOF	See Section 4.12	

The oxygen ventilation circuit receives oxygen from the primary oxygen system and/or SOP, circulates the oxygen through the SSA, removes CO_2 and other contaminants, removes condensate and heat, and repeats the process.

Oxygen enters the ventilation circuit from the primary oxygen system and SOP upstream of the suit pressure sensor. Pressure data from the suit pressure sensor is continually sent to the CWS and can be read on the DCM display by the crewmember. The suit pressure also is measured by the suit pressure gauge on the DCM. Because the gauge is mechanical, no data are sent to the CWS. Another difference between the gauge and the sensor is that the gauge reads directly into the SSA pressure cavity, while the sensor senses pressure in the vent loop line.

Downstream of the suit pressure sensor, the vent flow passes the inlet to CO_2 sensor. A flow limiter allows less than 1 percent of the ventilation flow to divert to the CO_2 sensor. The sensor's measurement of CO_2 levels in the vent loop indicates whether the CCC is functioning properly. It is important to keep in mind that the CO_2 sensor does not measure the level of CO_2 in the helmet. The level of CO_2 at the crewmember's face can be up to twice as high as the reading from the sensor. The CWS alert and warning levels are set accordingly. The continuous data from the CO_2 sensor are, like the suit pressure sensor, sent to the CWS and can be read on the DCM display by the crewmember. The sensor performs a self-test on startup and, if it fails the self-test, it is designed to read off-scale high at 30 mmHg. The sensor also fails off-scale high if water enters the sensor cavity. If the sensor fails, cycling suit power may recover it.

Past the inlet to the CO_2 sensor, the vent flow enters the SSA behind the helmet vent pad. The vent pad directs the flow upward to the top of the helmet, then the gas flows downward over the visor and face. This washes away CO_2 and humidity, helps prevent the visor from fogging, and cools the crewmember's head. The flow continues into the HUT, arms, and LTA. When the flow gets to the ends of the arms and legs, it enters vent ducts on the LCVG. The four ducts meet at a manifold at the crewmember's back. This manifold directs the flow through a single duct that connects to the MWC on the HUT. The flow then returns to the PLSS through a duct in the HUT.

Back in the PLSS, the flow enters the CCC. For specifications on the CCC, see Section 3.6. The CCC removes CO_2, odors, particulates, and trace contaminants from the ventilation flow. The chemical reaction that does this also heats and humidifies the gas exiting the CCC.

Past the CCC, the vent flow enters a centrifugal fan. The fan drives the flow in the ventilation circuit and is powered by a brushless dc electric motor. One shaft of the motor directly powers the fan and water separator. The motor also powers the water pump in the liquid transport system (Section 3.1.3) through a magnetic coupling. The motor, and therefore the fan, pump, and water separator, are all controlled by the FAN switch on the DCM. In the event of a motor or switch failure, all three components are lost.

During suit operations, the fan operates in two different modes:

a. Continuous power

b. Speed control

If the absolute suit pressure is approximately 10 psia or higher, the vent flow gas density is relatively high. This creates the highest load on the fan. Therefore, the fan must be continuously powered to reach nominal operating speed of 18,000 to 20,000 rpm. Under these conditions, the fan/motor speed is inversely proportional to absolute suit pressure and the current draw is directly proportional to absolute suit pressure.

However, when the absolute suit pressure is approximately 10 psia or lower, the vent flow gas density is lower, thus there is less load on the fan as it rotates. The motor electronics convert rotation speed to a voltage signal and use this signal to maintain the fan/motor speed at 18,000 to 20,000 rpm. This is done by pulsing power to the motor windings as needed, so the windings are not pulsed every revolution. This speed control mode uses less power to operate the fan/motor. During suit operations with a cabin pressure of 10.2 psia, the fan has switched from continuous power mode to speed control mode and back, depending on the rotation speed. EMU checkout procedures verify speed control operation by instructing the crewmember to turn the fan on, note the EMU input amps on the airlock panel, then install the SCOF. With the SCOF installed, vent flow is stopped, reducing the load on the fan. This should cause the fan to operate in speed control mode. The crewmember then rechecks the EMU input amps. Because the motor uses less current in speed control mode, the amp reading should be less than it was before the SCOF was installed.

If there is a problem with the fan, there are two cases that cause the motor electronics to shut it down:

a. Fan speed does not reach 13,000 rpm within 5 sec of activation.

b. Fan speed drops below 13,000 rpm during operation.

These features ensure that the fan starts properly and protect the motor bearings in case of a failing fan.

The fan draws vent flow into the sublimator (Figures 3-5 and 3-6), which cools and dehumidifies the gas. As the flow enters the sublimator, moisture in the gas condenses on the walls. A

hydrophilic ceramic coating on the walls attracts the moisture and prevents puddling. At the end of the vent flow passage, there are holes that lead to a passage called the slurper header. Through the water separator, the fan draws a slight suction on these holes. This suction draws condensate through the holes and creates capillary action that wicks the condensate, as it forms, along the vent flow passages to the slurper holes.

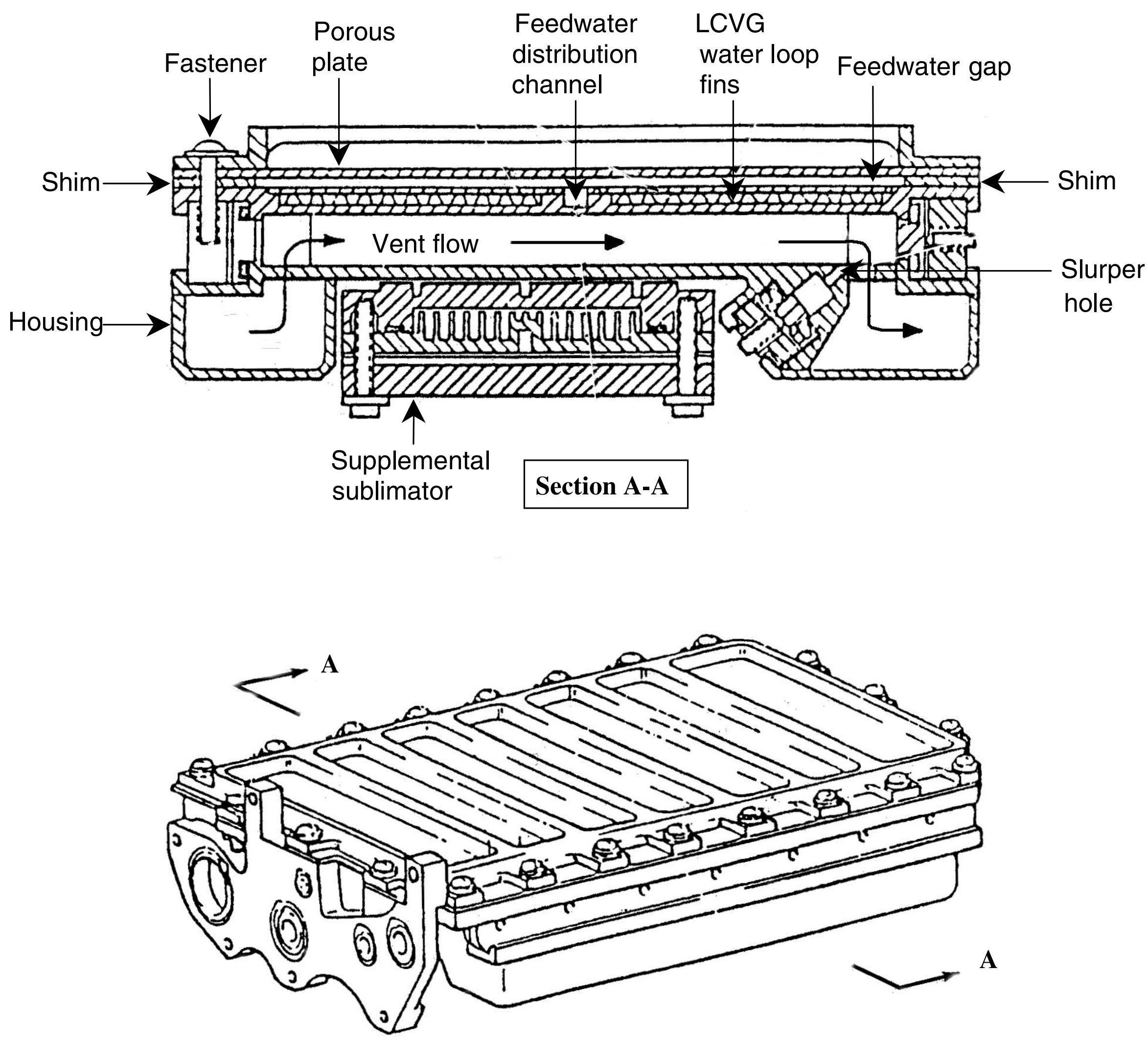

Figure 3-5. Sublimator

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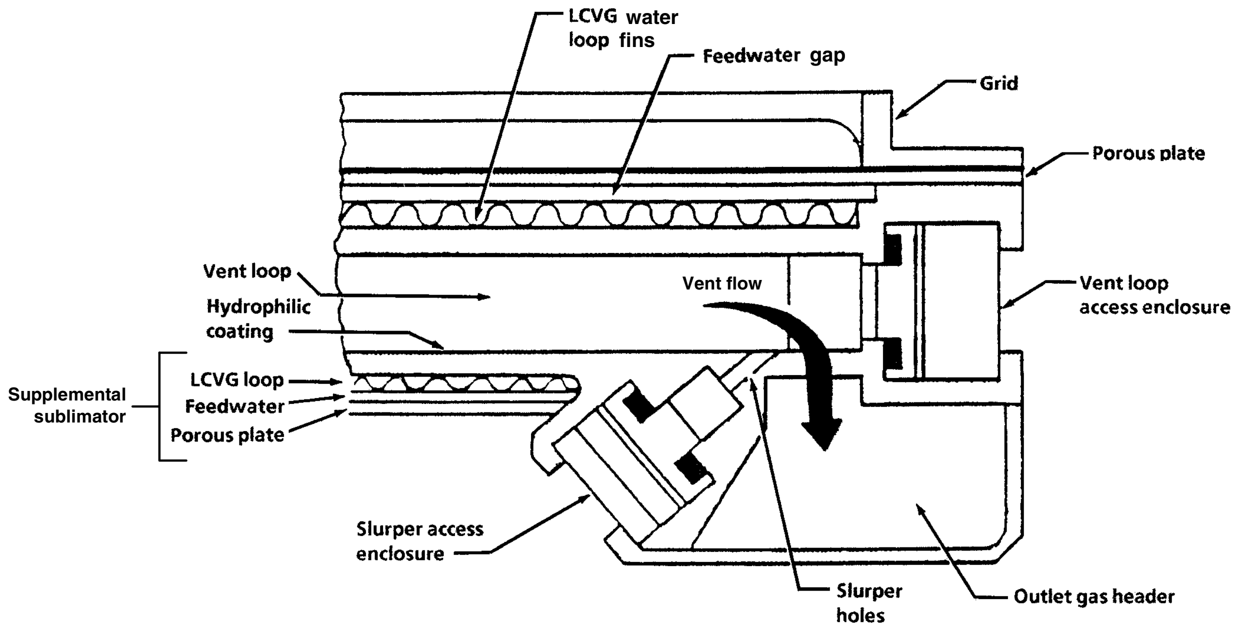

Figure 3-6. Sublimator closeup cross section

Approximately 1 to 10 percent of the ventilation gas flow accompanies the condensate into the slurper. The fan draws this mixture into the motor-driven rotary water separator. A rotating drum spins condensate to the outer edge of the housing and into a Pitot tube. The water then flows back to the feedwater circuit and becomes available as consumable water. The dried vent gas flows through the center of the drum and returns to the vent circuit.

Downstream of the sublimator is a vent flow sensor/backflow check valve. This item has two functions:

a. Directs all purge flow to the helmet when the fan is unpowered or failed.

b. Indicates adequacy of ventilation circuit flow rate.

The backflow check valve is a flapper valve that is closed across the vent line when there is little or no flow. When there is nominal flow in the system, the flapper valve is held open by the gas flow. The vent flow sensor is a contact switch that senses when the flapper is open and closed. The position of the backflow check valve indicates adequacy of vent flow. This is necessary to ensure that CO_2 does not build up in the helmet. Without enough ventilation flow, the CO_2 level in the helmet could increase even if the CO_2 sensor indicated that the CCC was performing nominally. If the ventilation circuit flow falls below 3.7 acfm, the backflow check valve closes and the vent flow sensor sends a NO VENT FLOW signal to the CWS. If and when the flow increases to 5.1 to 5.7 psia, depending on absolute suit pressure, the backflow check valve opens and the vent flow sensor sends a message to the CWS indicating flow is good. The sensor automatically compensates for the change in vent circuit pressures so that the set and reset points are correct.

The backflow check valve also ensures that when the fan is unpowered or failed, all purge flow is directed to the helmet.

The ventilation loop contains several valves located throughout the EMU to provide purge, pressure relief, and nominal checkout capability during various modes of operation.

If the fan malfunctions or if the PLSS fails to remove CO_2, heat, or humidity from the vent circuit, a contingency operation exists to open either the helmet purge valve or the DCM purge valve.

Note: These valves should never be open at the same time because the flow rate would exceed the SOP flow capability to maintain suit pressure.

Opening the helmet purge valve opens the ventilation loop because some of the oxygen flowing into the helmet exits the purge valve. This provides a path for CO_2 and humidity to be washed out of the suit; it is referred to as an open loop purge. The helmet purge valve is manually actuated and must be locked in both the OPEN and CLOSED positions by the crewmember so that the flow rate out of the valve is known. With the helmet purge valve open, the SOP regulator ensures suit pressure remains at least 3.33 to 3.9 psid. In this helmet purge mode, the SOP can support the crewmember for approximately 45 minutes at a metabolic rate of 1000 BTU/hr. CO_2 and humidity are removed, but no crewmember cooling is provided in this mode.

A secondary open loop purge mode also can be initiated by the crewmember if cooling is required. First, the helmet purge valve must be closed and locked, then the DCM purge valve may be opened. Now oxygen is delivered to the helmet, flows into the suit to the ends of the arms and legs, and returns via the LCVG vent ducts to the multiple water connector on the HUT. From there, flow exits the suit via the DCM purge valve. In this mode, suit pressure is maintained to no less than 3.33 to 3.9 psid, and the SOP can support the crewmember for approximately 30 minutes at a metabolic rate of 1000 BTU/hr. Heat, humidity, and CO_2 are removed.

The DCM purge valve also is used to purge N_2 from the suit prior to a prebreathe period. It locks in the OPEN and CLOSED positions.

The Positive Pressure Relief Valve (PPRV) in the ventilation circuit protects the EMU from overpressurization. If suit pressure increases more than 4.7 psid above ambient, the PPRV opens to vent the excess pressure out of the EMU. This procedure occurs nominally during airlock depress. It also could occur if the suit pressure regulator or SOP second-stage regulator were to fail open or high. The PPRV can pass a higher flow rate than either the primary oxygen system's flow restrictor or the SOP's second-stage regulator, thereby preventing suit damage.

During an emergency repress of the airlock, the SOP may not be able to maintain suit pressure above ambient pressure. The negative pressure relief valve opens to allow ambient gas to flow into the suit to prevent the suit from collapsing on the crewmember.

The ventilation circuit is used to check the SOP during EMU checkout. The PLSS contains an SOP checkout relief valve which, in the past, was used to provide overpressure protection of the ventilation circuit during SOP check. This component, while still in the EMU, is no longer used because of corrosion problems that made the relief valve unreliable. A separate item, the SCOF, is now used. See Section 4.12 for a discussion and photo of the SCOF.

3.1.3 Liquid Transport System

The liquid transport system, or the cooling loop, circulates water through the LCVG to cool the crewmember.

The system includes the following components:

a. Pump (I123C)

b. Temperature Control Valve (TCV) (I321)

c. LCVG bypass plate

d. SCU bypass valve (located in I330, DCM multiple connector)

e. LCVG (I107) (See Section 2.6)

f. Sublimator (I140)

g. Sublimator outlet temperature sensor (I139)

h. Gas trap (I141)

i. Pump priming valve (I125)

j. Cooling water check valve (I128)

k. Filters

Table 3-4 lists the specifications for the liquid transport system.

Table 3-4. Liquid transport system specifications

Item	Parameter	Specification
System	Normal operating pressure	15.15 ± 0.55 psid
	Maximum operating pressure	28.1 psid
Pump	Flow produced during EVA	15 to 240 lb/hr
	Head produced during EVA	4.5 psid minimum
LCVG bypass plate	Orifice flow	12 lb/hr minimum
Sublimator	Maximum outlet water temp.	52.5° F
	Heat rejection; maximum operating	2000 BTU/hr for 15 minutes
	Heat rejection; minimum operating	400 BTU/hr for 30 minutes
Sublimator outlet temperature sensor	Operating temperature range	32 to 104° F
	Accuracy	±1.5° F
Pump-priming valve	Auto open pressure	5 psid
	Auto close pressure	2 psid
	Manual actuation force	3 to 9 lb
Cooling water check valve	Flow	260 lb/hr

In this system, water is circulated through the LCVG to cool the crewmember. Water exiting the LCVG flows toward the pump. Upstream of the pump is a gas trap that removes gas from the loop to prevent the pump from cavitating. The gas trap contains a screen that passes water but blocks gas bubbles. Most of the water continues to the pump, but the bubbles and a minimal amount of water exit the trap through seven orifices leading to the water separator. The bubbles are drawn through the orifices by the approximately 11-psid pressure differential between the cooling loop (~15 psi) and the vent loop (~4 psi).

Downstream of the gas trap, the circuit has a connection to the feedwater circuit. This supply connection makes up for the water that exits the liquid transport circuit through the gas trap. A check valve between the gas trap and the connection to the feedwater circuit ensures that any water entering the liquid transport circuit flows toward the pump to flush gas bubbles from the pump.

A Pitot-actuated pump-priming valve is located between the gas trap and the water separator. The valve prevents water in the liquid transport system from entering the water separator unless the separator is operating properly. If the water separator is not operating properly, water flowing through it floods the ventilation circuit.

The pump-priming valve can be opened and closed automatically or manually. During normal operation, the valve is open so that the cooling loop can be degassed. It opens automatically when the pressure differential between the water outlet of the separator and the inlet of the pump-

priming valve indicates that the water separator is functioning properly. When the separator is off, starting up, or shutting down, the valve is closed. When the separator is operating nominally, it produces a pressure head and the valve is opened.

The valve can be manually opened to prime the pump, flushing any gas bubbles out that may be present on startup. Indicators to the crewmember that there are bubbles in the pump include hearing a rapid tapping noise that resembles a chainsaw sound, not feeling cooling, or not seeing flow in the LCVG. To manually open the valve, a crewmember pushes a button accessible from the rear of the PLSS (Figure 3-7). By opening this valve, gas and liquid are removed from the circuit through the gas trap. Water from the feedwater circuit enters the liquid transport system, and the check valve directs it through the pump. This priming process takes only a few seconds (~30 sec).

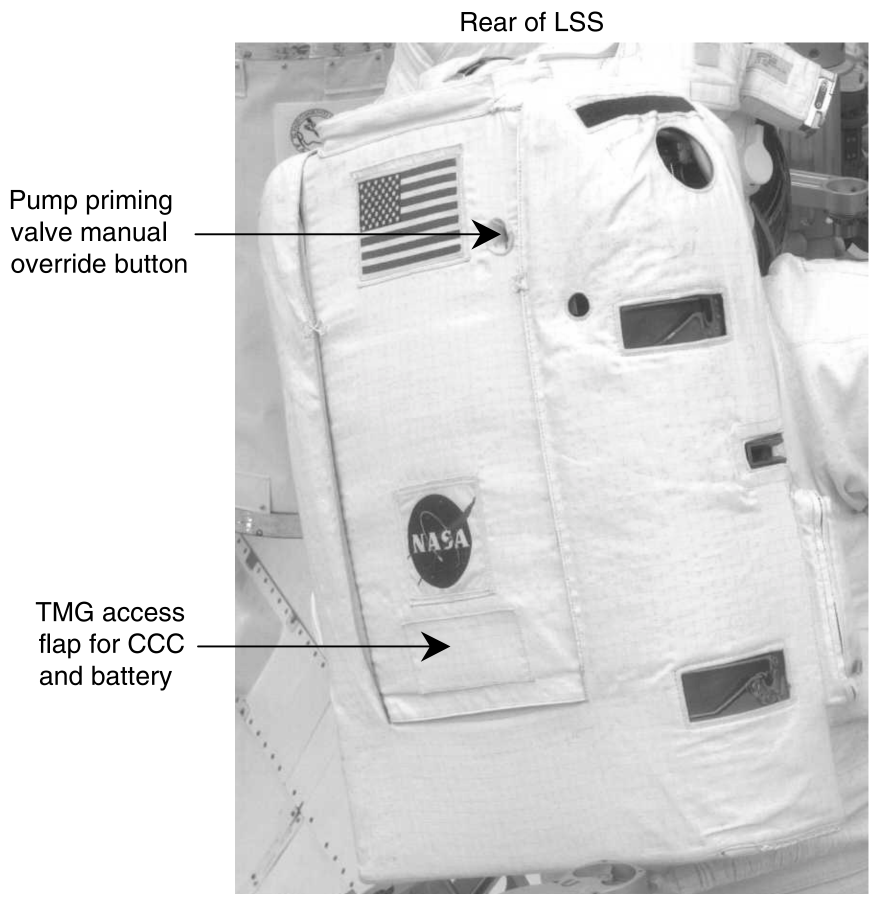

Figure 3-7. Pump-priming valve access

The electric motor drives the pump via a magnetic coupling. The magnetic coupling, rather than a mechanical coupling, reduces the need for seals and the risk of getting water from the cooling loop on the electric motor. As mentioned in Section 3.1.2, the motor, and therefore the fan, pump, and water separator, are all controlled by the FAN switch on the DCM. In the event of a motor or switch failure, all three components are lost. Both the pump and the water separator need water to operate properly. If there are gas bubbles in the pump, the pump cavitates and

does not produce flow in the circuit. The water flowing through the pump also cools the pump bearings.

During an EVA, warm water from the LCVG exits the pump and flows into the HUT to the TCV on the DCM (Figure 3-16). Cooled water from the sublimator (or orbiter heat exchanger, if on SCU) also flows to the TCV. The TCV, a mixing valve, controls the amount and temperature of the water flowing through the LCVG. The crewmember can adjust the TCV from Maximum Cold (Max. C) to Maximum Hot (Max. H). The TCV settings (Max. H, 0-10, Max. C) are marked on the DCM thermal cover so that the crewmember can read them with a wrist mirror. Depending on the TCV's position, the system operates in one of several modes:

a. Max. C position - Only cold water flows to the LCVG. All the warm water is sent to be cooled by the sublimator or orbiter heat exchanger.

b. Positions Max. C through 2 - Both warm and cold water flow to the LCVG. The remaining warm water diverts toward the sublimator or orbiter heat exchanger.

c. LCVG bypass mode (between positions 2 and Max. H) - Only warm water flows to the LCVG. There is no flow through the sublimator. These positions begin LCVG bypass mode. As the setting moves toward Max. H, flow through the LCVG decreases.

d. Full LCVG bypass mode (Max. H) - There is no flow through the LCVG. Warm water exits the pump, flows through the SCU bypass valve and the LCVG bypass plate, and returns to the pump. The crewmember receives no cooling. This helps the crewmember stay warm in cold environments.

In all cooling loop operations, some of the warm water returning toward the sublimator diverts through the LCVG bypass plate to the pump inlet line. The plate is located at the PLSS-HUT interface. In full LCVG bypass mode, this flow is needed to cool the motor/fan/pump/water separator and DCM electronics.

When the SCU is connected, the SCU bypass valve in the DCM is closed. The pump circulates warm water out of the EMU, through the SCU, to the orbiter LCVG heat exchanger to be cooled, and back into the EMU from the SCU. The water flow path still includes the sublimator, but no cooling from the sublimator is needed. Instead, the water from the cooling loop cools the sublimator so that the vent loop gas is cooled and moisture can condense out of the gas. When the SCU is disconnected, the DCM cooling fittings are closed and the SCU bypass valve is open.

The sublimator cools the water in the system while EVA and not connected to the SCU. Section 3.1.4 describes how the sublimator operates.

The outlet temperature sensor of the sublimator sends a continuous signal to the CWS indicating the temperature of the cooling water as it exits the sublimator. The CWS uses this measurement and displays it to the crewmember on the DCM.

3.1.4 Feedwater Circuit

The feedwater circuit performs the following functions:

a. Removes heat from the EMU.

b. Supplies the liquid transport loop with makeup water, thereby pressurizing it.

c. Stores vent loop condensate.

The circuit includes the following components:

a. Feedwater tanks (two primary, one reserve) (I131, I148, I162)

b. Feedwater supply pressure sensors (two) (I132A & B)

c. Feedwater pressure regulator (I136)

d. Feedwater shutoff valve (I137)

e. Feedwater pressure sensor (I138)

f. Sublimator (I140)

g. Reserve feedwater tank relief valve (I142)

h. Reserve feedwater tank check valve (I143)

i. Water separator (I123B)

j. Condensate water relief valve (I134)

k. Coolant relief valve (I172)

l. Coolant isolation valve (I171)

m. Feedwater relief valve (I135)

n. Filters

Table 3-5 lists the specifications for the feedwater circuit.

Table 3-5. Feedwater circuit specifications

Item	Parameter	Specification
Feedwater tanks	Pressure, norm. operating	15.15 ± 0.55 psid
	Quantity, both primary	8.3 lb
	Quantity, reserve	0.83 lb
Feedwater tank pressure sensors	Range	0 to 40 psia
	Accuracy	±2.5 percent F.S. (±1 psi)
Feedwater pressure regulator	Regulation pressure	2.05 to 4.15 psid
Feedwater pressure sensor	Range	0 to 16 psia
	Accuracy	±2.5 percent F.S. (±0.4 psi)
Reserve tank relief valve	Relief pressure	4.0 psid minimum
	Reseat pressure	3.0 psid minimum
Reserve tank check valve	Relief pressure	1.0 psid maximum
	Reseat pressure	0.3 psid minimum
Condensate water relief valve	Relieve/reseat pressure	2.0 to 3.2 psid
Coolant relief valve	Cracking pressure	0.3 psid minimum
	Reseat pressure	0.1 psid minimum
Feedwater relief valve	Relieve/reseat pressure	19.0 ± 1.0 psid

The crewmember, PLSS components, suit electronics, and the space environment all impose heat loads on the EMU. The feedwater circuit supplies water to the sublimator when at vacuum to dissipate these heat loads. During IV operations, the orbiter cools the EMU through the SCU. The feedwater system also provides makeup water as needed to the cooling loop, thereby pressurizing it.

Two primary water tanks and one reserve water tank store water for sublimator operations. Historically, only about half of the primary water has been used during an EVA. The tank bladders are made of a flexible material called Fluorel and are pressurized by the primary oxygen system. The 15-psid range of this system was selected so that any dissolved gas stays in solution during EVA.

Two feedwater tank pressure sensors allow the CWS to determine when the primary tanks are empty. One sensor measures the pressure the oxygen circuit is imposing on the bladders (called the water/gas pressure), and the other sensor measures the pressure downstream of the bladder openings (called the water/water pressure). If the water/water pressure drops below the water/gas pressure, it means that the bladders are fully compressed, and therefore empty. A pressure differential between the two sensors of more than 2.0 psi, their combined error band, causes the CWS to start a 30-minute timer and alerts the crewmember that the primary tanks are empty.

The reserve feedwater tank contains water that is used if the primary water tanks become depleted during an EVA. The tank contains enough water to cool the EMU for approximately 30 minutes at a metabolic rate of 1000 Btu.

Downstream of the reserve tank, the reserve tank relief valve prevents reserve feedwater from being used until the primary tanks are empty. When the primary tanks are empty, the pressure downstream of the valve drops below the pressure upstream of it. A 4.0-psid pressure differential causes the valve to open, allowing the reserve water to be used.

On orbit, the feedwater tanks are filled through a connection on the DCM to the SCU. The reserve tank check valve, in parallel with the reserve tank relief valve, opens during water fill to allow water into the reserve tank. The valve opens when there is a pressure differential of 1.0 psid across the valve.

The feedwater relief valve provides overpressure protection for the system. If the pressure across the valve exceeds 19.0 psid, the valve bleeds excess water to ambient.

Downstream of the H_2O feedwater supply pressure sensor (water/water pressure sensor), the feedwater flows toward the sublimator (Figure 3-8). The sublimator provides all the EMU heat removal capability when not on the SCU. When at vacuum, feedwater enters the sublimator cavity and flows into one side of a stainless steel porous plate. The other side of the plate is exposed to vacuum. As the water passes through the plate, it freezes, sublimates to gas, and escapes to space. As the feedwater sublimates, it absorbs and removes heat from the EMU, cooling the water in the cooling loop and the gas in the vent loop.

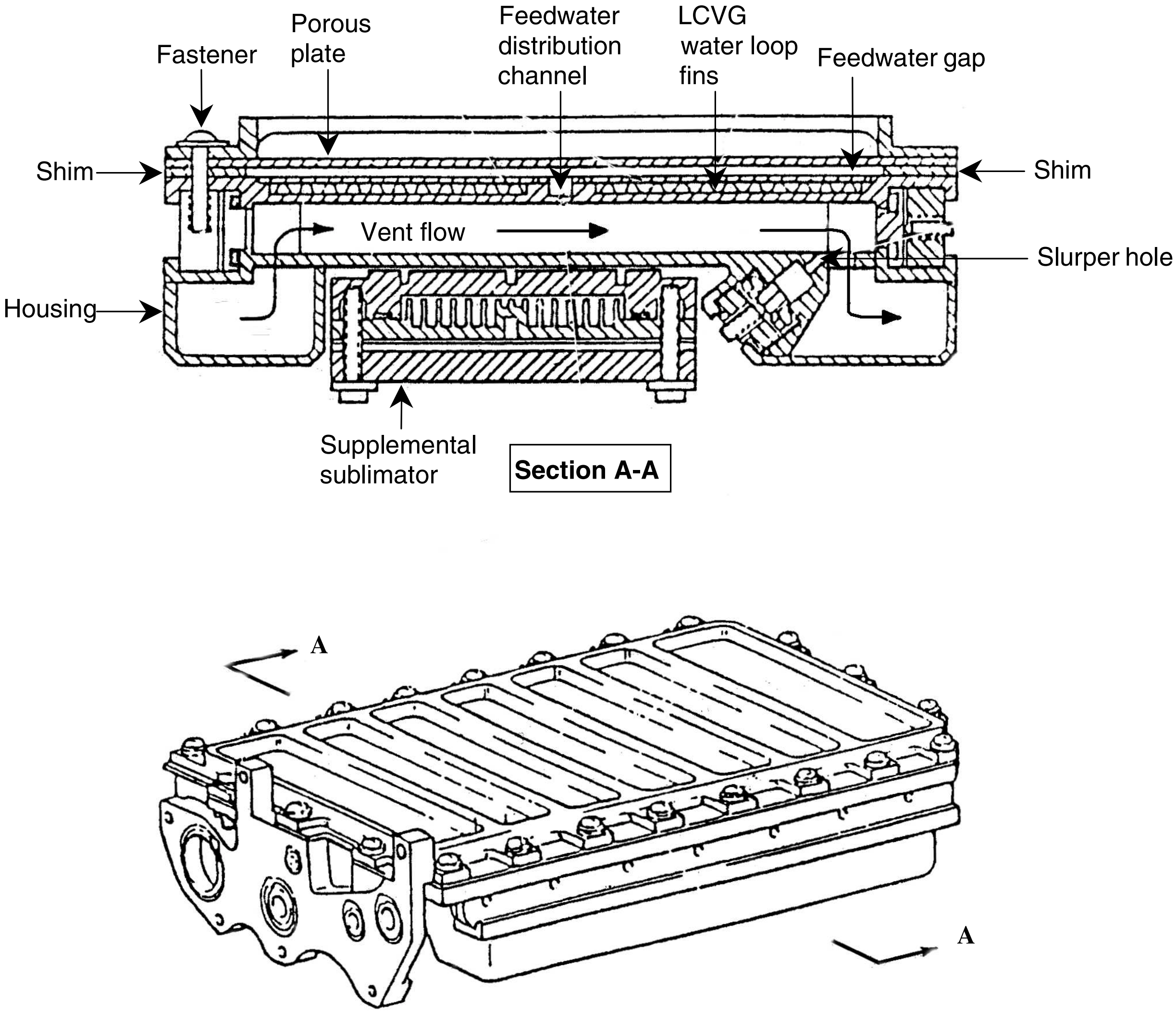

Figure 3-8. Sublimator

Before entering the sublimator, feedwater passes through the feedwater pressure regulator. This regulates the water to the pressure the sublimator needs, 2.05 to 4.15 psid. Higher or lower pressures result in less heat rejection to space. High pressures can cause the sublimator porous plate to deflect, increasing the gap between the plate and the sublimator core. This results in poor heat transfer from the core to the plate. Higher pressure also can cause water to leak directly to space without first freezing in the porous plate. This reduces heat transfer and uses feedwater at a higher than optimum rate. Lower pressures result in incomplete water coverage of the porous plate, reducing the area available to reject heat to space.

Downstream of the feedwater pressure regulator is the feedwater shutoff valve. The crewmember controls the position of this valve with the water switch on the DCM. When closed, the valve prevents water from flowing to the sublimator. The valve is not opened until the EMU is exposed to vacuum. If water were already in the sublimator as pressure decreases to vacuum, that water could freeze in the sublimator cavity and warp the sublimator porous plate.

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The valve is solenoid-actuated and magnetically latched. If the valve fails or EMU power is turned off, the valve position does not change.

The feedwater pressure sensor, between the feedwater shutoff valve and the sublimator, sends a continuous signal to the CWS that indicates the feedwater pressure at the sublimator inlet. The CWS uses this measurement and displays it to the crewmember on the DCM. During IV operations and airlock depress/repress, the water switch is off and this sensor senses ambient pressure through the sublimator. In this situation, it can be used as an airlock pressure sensor.

The feedwater circuit also provides storage for condensate from the vent loop. Water from the water separator flows first to the condensate water relief valve. This valve has two functions:

a. Prevents pressurized feedwater from flooding the vent loop through the water separator when the separator is off.

b. Provides backpressure to signal the pump-priming valve to open.

Downstream of the condensate water relief valve is the coolant relief valve. This valve prevents flooding of the water separator in case the condensate water relief fails open.

The FAN switch on the DCM controls the coolant isolation valve; the valve is open when the switch is on and closed when it is off. The valve, like the feedwater shutoff valve, is solenoid actuated and magnetically latched. If the valve fails or EMU power is turned off, the valve position does not change. The valve performs the following functions:

a. Prevents flooding of the vent loop. This valve backs up the condensate water relief valve and the pump-priming valve. If either of those valves should fail open with the water separator off, feedwater could flood the vent loop through the water separator.

b. Allows the feedwater tanks to provide makeup water to the cooling loop.

3.2 Secondary Oxygen Pack

The SOP (I200) provides:

a. Emergency EMU oxygen supply

b. Emergency EMU pressure regulation

c. Emergency open loop purge capability

SOP components include:

a. Secondary oxygen tanks (two) (I210)

b. SOP pressure sensor (I215)

c. SOP pressure control module (I213), which includes:

   (1) Oxygen fill connector (I213F)

   (2) SOP tank pressure gauge (I213E)

   (3) Two-stage regulator (I213B & D) with these integral features:

      (a) Shutoff

      (b) Flow restriction

      (c) Check valve

   (4) Test port

   (5) First-stage regulator outlet pressure gauge (interstage pressure gauge) (I213G)

   (6) Manual override

d. PLSS/SOP interface connector

Table 3-6 lists the SOP specifications.

Table 3-6. Secondary oxygen pack specifications

Item	Parameter	Specification
System	Maximum use time, DCM purge	30 min
	SOP flow activation	Suit P drops below ~3.9 psid and O_2 ACT - EVA
	Maximum charged weight	23.1 lb
Secondary oxygen tanks	Pressure, nominal	6000 ± 200 psia
	Total quantity usable O_2	2.631 lb minimum
	Usable pressure range	365 to 7400 psia
	Volume per tank	89.2 in3
SOP pressure sensor	Range	0 to 7400 psig
	Accuracy	±3.5 percent F.S. (±259 psi)
SOP tank pressure gauge	Range	0-8000 psig
	Accuracy	±5.0 percent F.S. (±400 psi)
First-stage regulator	Regulation pressure	~200 psi
Interstage pressure gauge	Range	0 to 8000 psig
	Accuracy	±5.0 percent F.S. (±400 psig)
	Nominal pressure indication	~200 psig
Second-stage regulator	Regulation pressure	3.33 to 3.9 psid, flow-dependent
	Regulated flow rate	0.06 to 5.26 lb/hr
	Maximum flow rate	7.49 lb/hr

The SOP provides emergency Fail Safe capability for the EMU (Figures 3-9 and 3-10). It is attached to the bottom of the PLSS and is active only when the O_2 actuator on the DCM is in the EVA position. SOP use begins if suit pressure drops below the SOP regulation pressure. Causes of this condition may include:

a. Exhaustion of the primary oxygen system

b. Helmet or DCM purge valve is opened, initiating open loop purge mode

c. Suit puncture (a 1/6-inch-diameter hole flows about the same as the DCM purge valve)

The system allows the crewmember time to return to the airlock and repressurize. It has never been used on orbit.

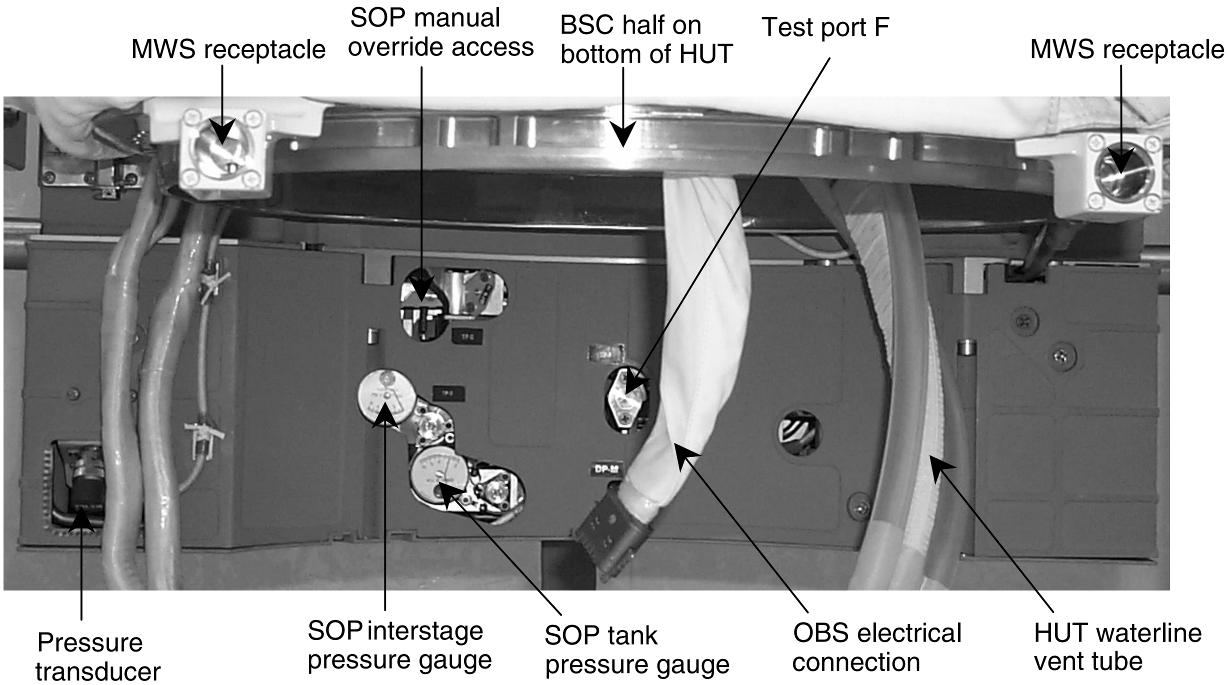

Figure 3-9. SOP

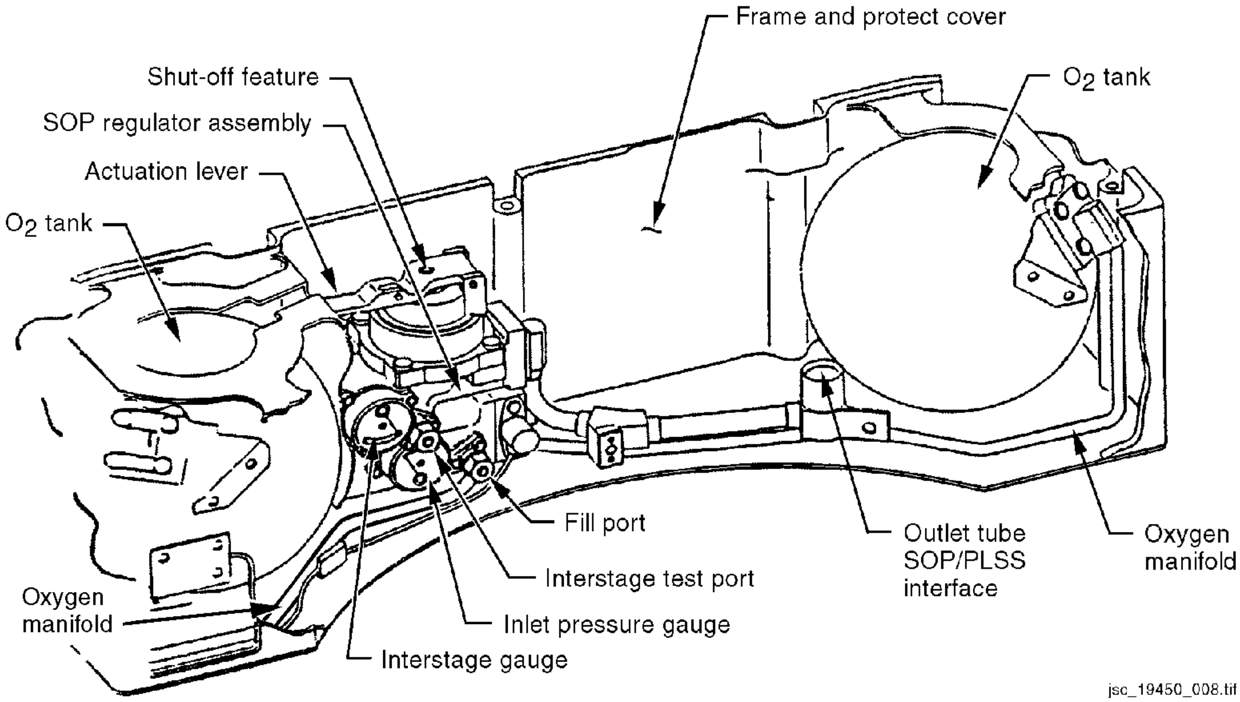

Figure 3-10. SOP drawing

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The secondary oxygen tanks store oxygen at high pressure, which allows the required quantity to be stored in a small volume. The orbiter does not have a pressurized oxygen source that high, so the tanks can be filled only on the ground. The tanks are critical pressure vessels, which means that any defects will cause leaks before the bottles lose structural integrity and burst.

Downstream of the tanks is the SOP pressure sensor. This sensor sends a continuous signal of the tank pressure to the CWS and the DCM display. The CWS uses this information to determine the time remaining during emergency usage and to send audible alarms to the crewmember.

The SOP tank pressure gauge provides a mechanical indication of tank pressure. This gauge, the interstage gauge, and the manual override lever face forward toward the crewmember so are accessible only when the LTA is not attached to the HUT (Figure 3-11).

Next, the first-stage regulator lowers the line pressure. This makes it easier for the second-stage regulator to control suit pressure accurately. The lower pressure also is necessary to limit maximum flow in case the second stage fails open.

The interstage gauge indicates pressure between the two regulator stages. It allows the crew to detect a failed open or leaking first-stage regulator during EMU checkout. The first-stage regulator has a higher allowable leakage than the second stage; therefore, line pressure between the two may rise to tank pressure. This means the interstage gauge must be able to read from its nominal low range all the way up to tank pressure.

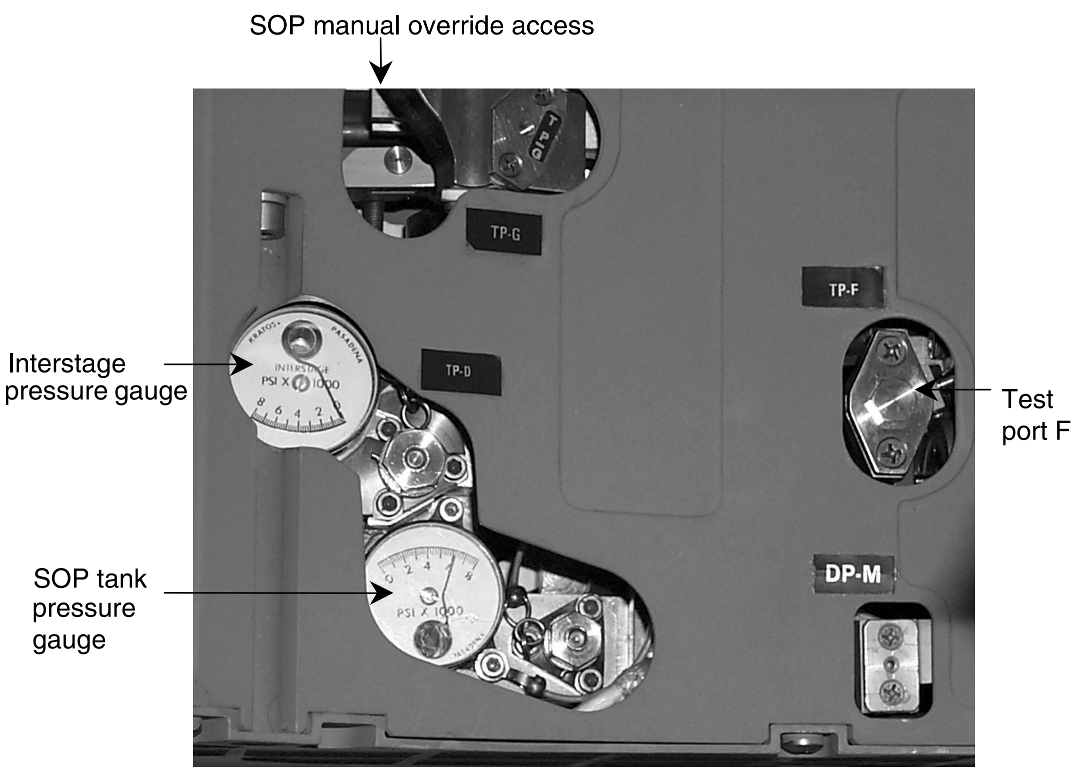

Figure 3-11. SOP gauges

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The second-stage regulator acts as a shutoff valve in all O_2 actuator positions except EVA. In the EVA position, it attempts to regulate suit pressure, but to a lower pressure than the suit pressure regulator of the primary oxygen system. Only if suit pressure drops does the SOP get used. This design makes SOP activation automatic. The second stage can regulate suit pressure nominally even if the first stage fails open and the inlet to the second stage sees full tank pressure. The flow-limiting feature keeps flow into the suit less than the maximum flow out of the positive pressure relief valve, but only if the first stage is functioning properly. If both the first- and second-stage regulators fail open, the suit can rapidly overpressurize and rupture. The last feature of the second stage is a check valve. If the SOP tanks leak, or the SOP system pressure drops to zero in some other way, this check valve prevents primary oxygen from flowing into the SOP.

A manual override of the second-stage regulator allows the SOP to be checked during EMU checkout. With the SCOF attached and the O_2 actuator in OFF, depressing the manual override lever opens the second-stage regulator and allows it to pressurize the portion of the vent loop from the SOP to the vent at the HUT neck ring. Checking SUIT P on the DCM display indicates whether the second-stage pressure regulation is nominal or off-nominal. If the first stage has leaked, the interstage gauge may indicate tank pressure. By manually opening the second-stage regulator, this gas escapes to pressurize the vent loop. This allows the crew to check first-stage regulator operation with the interstage gauge.

The PLSS/SOP interface connector attaches the SOP to the PLSS. The SOP is designed to be changed out on orbit, but this has never been attempted.

3.3 Space-to-Space EMU Radio

The SSER is one part of the Space-to-Space Communication System (SSCS). It interacts with the Space-to-Space Orbiter Radio (SSOR) and the Space-to-Space Station Radio (SSSR) and performs the following functions:

a. Allows voice communication between EV/EV and EV/IV crewmembers.

b. Allows voice communication between the EV crewmembers and the ground via ISS or the orbiter.

c. Sends biomed and EMU data to the orbiter and/or ISS for relay to the ground.

d. Generates status, alert, and warning tones sent by the CWS.

The system includes the following major components:

a. Transceivers (two)

b. Antenna

The system interfaces with the following EMU components:

a. CCA

b. DCM

c. SCU

d. CWS

e. RTDS

f. OBS

g. EEH

Table 3-7 lists the SSER specifications.

Table 3-7. SSER specifications

Item	Parameter	Specification
System	Range: EMU to EMU	75+ meters (246+ feet)
	Range: Orbiter to EMU	160+ meters (525+ feet)
	Range: ISS to EMU	80+ meters (262+ feet
	Transmit power	0.11 watts
Transceivers	Primary frequency	414.2 MHz
	Alternate frequency	417.1 MHz

This system allows the crewmember to communicate via radio signals or hardline connection through the SCU. The SSER connects to the top of the PLSS and primarily consists of two redundant UHF transceivers (Figure 3-12). Each transceiver is capable of operating on both SSCS frequencies.

The EMU antenna is a low profile, omnidirectional UHF antenna mounted on top of the SSER with Velcro (Figure 3-12). Its internal construction is a single hollow section that acts as a resonating cavity for radio signals in the frequency range of those used by SSCS. Thermal and electrical protection is provided by a TMG enclosure.

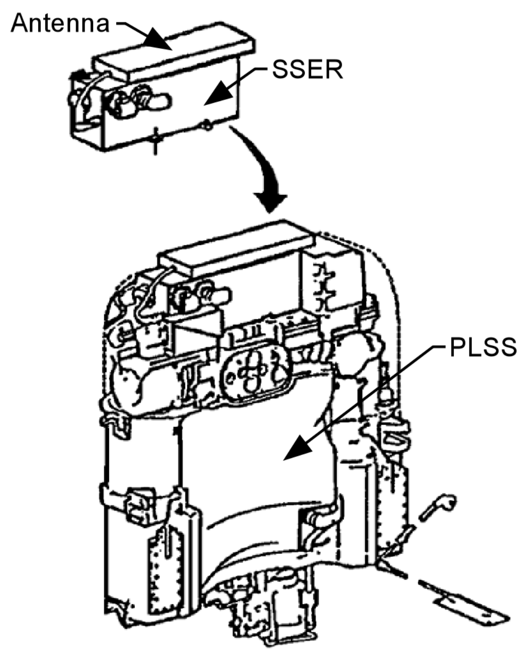

Figure 3-12. SSER and EMU antenna location

The EV crewmember communicates through the CCA, which is discussed in Section 2.8.

The SSER is controlled with switches on the DCM (Figure 3-13). The Communication mode (COMM) selector controls power to the transceivers. The HL switch enables hardline comm through the SCU. PRI enables the primary transceiver, ALT powers the alternate transceiver, and OFF completely powers down the SSER. When switching between PRI and ALT, there may be a delay of 1 to 3 seconds before comm is established due to warmup time for the transceiver.

Two separate volume control knobs are on the EMU DCM. These controls may be used in Radio Frequency (RF) or hardline communications. When the comm mode selector is in PRI, the upper volume control adjusts the level of all audio, including IV voice, ground voice (if present), EV voice, and sidetones. The lower knob adjusts all volume when in ALT. When attached to the SCU and in HL, the upper knob controls hardline volume and sidetone reception. Sidetones are the sounds of the crewmember’s voice routed to the earphones at a lower volume to verify transmission.

The operating frequency is determined by the position of the Communication Frequency (FREQ) switch. This three-position switch has fixed stops in the HIGH and LOW positions and is spring loaded in the Push-To-Talk/Mute (PTT/MUTE) position. In the LOW position, the powered transceiver operates at 414.2 MHz. LOW is nominally used for EVA. HIGH selects 417.1 MHz as the operating frequency.

Note: All users in the communication network must be operating on the same frequency to avoid disruption of comm.

When in RF comm, both the HIGH and LOW frequencies transmit when activated by voice. This is called Voice-Operated Transmission (VOX). Moving the FREQ switch to the momentary PTT/MUTE position may mute this continuous, automatic VOX. When in HL comm, this switch position allows microphone inputs to pass to the airlock Audio Terminal Unit (ATU) if the ATU is configured for PTT.

The EMU CWS sends signals to the SSER to produce status, alert, and warning tones that the crewmember hears in the CCA. These tones are added to the voice signals that the crewmember hears. The alert/status tone consists of a 1.5-kHz frequency. The warning tone has a warbling sound and is composed of a 1.5-kHz frequency pulse modulated with a 15-Hz square wave. Volume levels for these tones are fixed and cannot be changed by DCM controls.

In addition to audio signals, the SSER transmits other data that it receives from the EMU-RTDS. The RTDS sends Biomed and EMU data to the SSER; the SSER transmits the data; and the data are monitored in Mission Control Center (MCC). Biomed data come from the OBS, and EMU data come from the CWS. Both types are routed through the RTDS to the SSER. The data transmission occurs during a 120-second cycle, controlled by the RTDS: Biomed data are sent for 101 seconds, followed by 4 seconds of dead time, then EMU data are sent for 15 seconds.

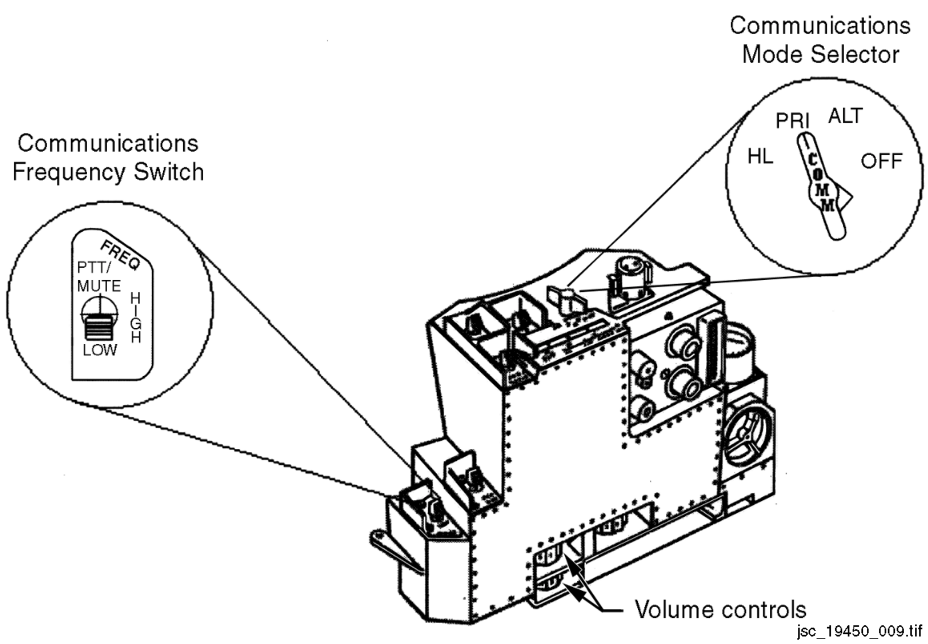

Figure 3-13. SSER controls on DCM

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Only the MCC surgeon monitors biomed data, and EVA monitors EMU data.

Power for the SSER can be provided either by the EMU battery or by the SCU (Figure 3-14).

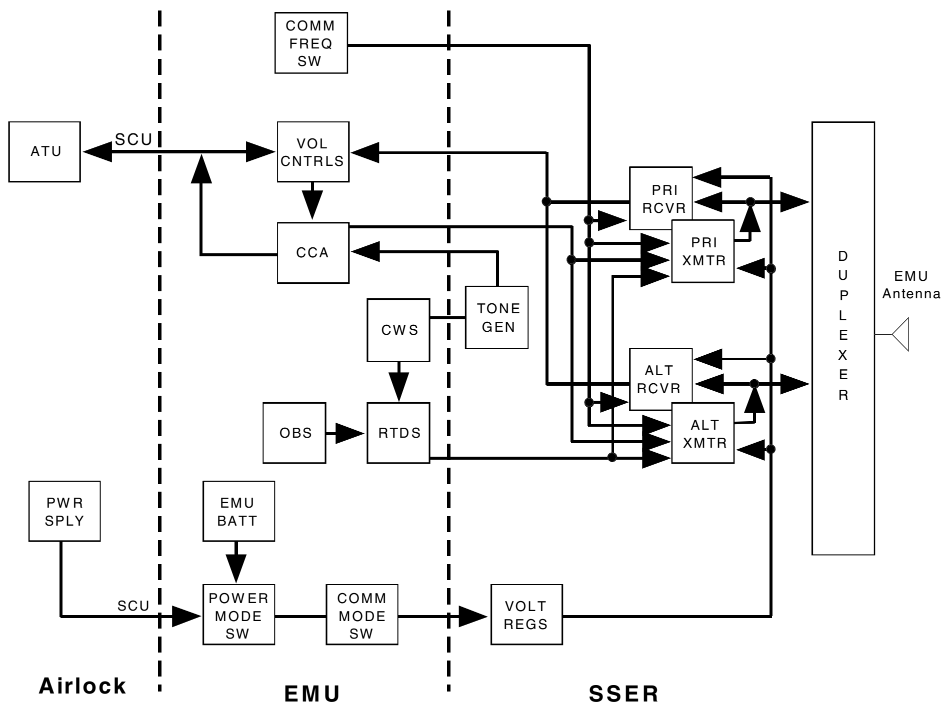

Figure 3-14. SSER interfaces

Refer to EVA Space to Space Communication System Training Workbook 2102 for more in-depth information on the SSCS.

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3.4 Display and Control Module

The DCM (I300) provides the controls and displays to operate and monitor the EMU.

The DCM includes the following components:

a. Suit pressure gauge (I311)

b. DCM purge valve (I314)

c. Temperature control valve (I321)

d. DCM multiple connector (I330)

e. Communications volume controls (I360)

f. Communications mode selector (COMM mode) (I362)

g. Communications frequency switch (comm FREQ) (I365)

h. Alphanumeric display (I351)

i. Display intensity control (I361)

j. POWER mode switch (I364)

k. FAN switch (I366)

l. WATER switch (I367)

m. DISPL (Display) switch (I368)

n. O_2 actuator (I115)

Table 3-8 lists the DCM specifications.

Table 3-8. DCM specifications

Item	Parameter	Specification
DCM multiple connector	Operating pressures:	
	Oxygen	0 to 1050 psid
	Potable water	8 to 20 psig
	Cooling water	28.1 psig maximum
	Nominal flow rates:	
	Oxygen	5 lb/hr
	Potable water	50 lb/hr
	Cooling water	240 lb/hr
	Operating voltage	18.5 ± 0.5 V dc

Figures 3-15 and 3-16 show the location of the controls and displays on the DCM. When the DCM is installed on the HUT, the surfaces of the DCM are covered with a TMG. This TMG contains the labels for the controls and displays.

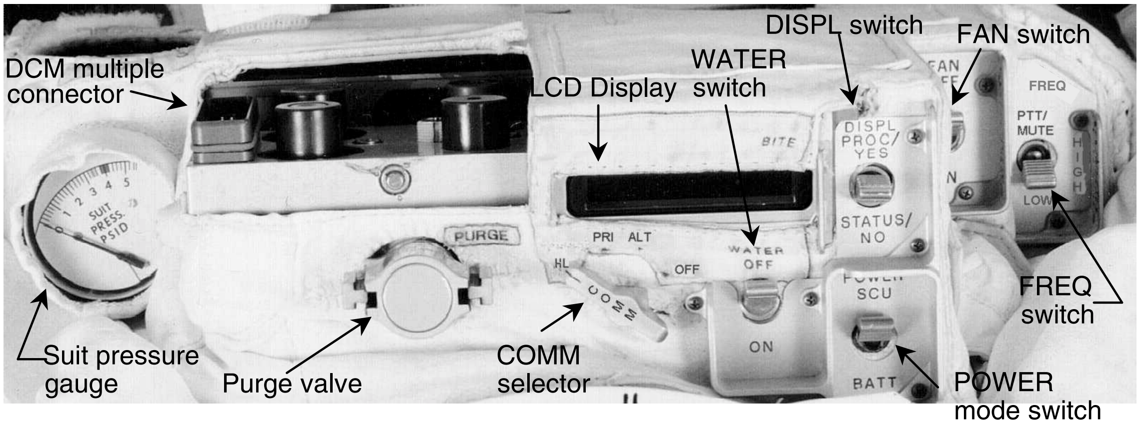

Figure 3-15. Top view of the DCM

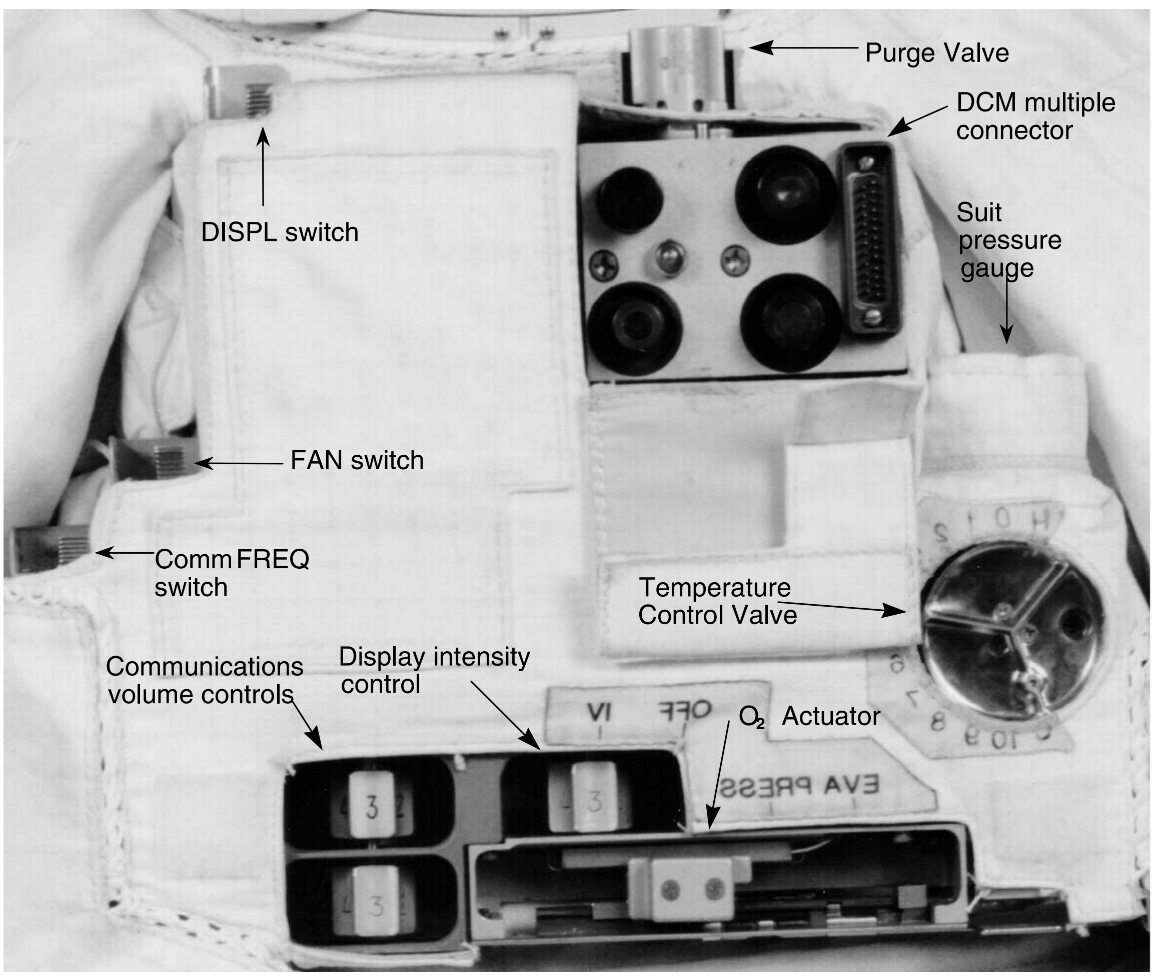

Figure 3-16. Front view of the DCM

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The following list describes the DCM components.

Component	Description
Suit pressure gauge	This gauge provides a mechanical indication of suit pressure. (See Section 3.1.2.)
DCM purge valve	This valve is opened to purge the EMU of nitrogen prior to prebreathe. In a contingency situation it also can be opened during EVA to remove heat, CO_2, and humidity. (See Section 3.1.2.)
Temperature control valve	By moving this valve's controller, the crewmember determines the amount of cooling provided by the liquid transport loop. (See Section 3.1.3.)
DCM multiple connector	This item allows the SCU to be attached to the EMU. Through the SCU, the EMU has access to vehicle electrical power, oxygen, potable water, and cooling water when in the airlock.
Communications volume controls	These two thumbwheels control radio volume. (See Section 3.3.)
Communications mode selector (COMM selector)	This switch controls power to the SSER transceivers. (See Section 3.3.)
Communications frequency switch (comm FREQ)	The position of this switch determines the operating frequency. (See Section 3.3.)
Alphanumeric display	This is a 12-character alphanumeric Liquid Crystal Display (LCD). It displays CWS messages and EMU system status information. (See Section 3.5.)
Display intensity control	This thumbwheel controls the intensity of the alphanumeric display.
POWER mode switch	This switch determines the EMU's power source. In the SCU position, power is drawn through the SCU. In the BATT position, power is drawn from the EMU battery. (See Section 3.7.)
FAN switch	This switch controls power to the EMU fan, pump, and water separator assembly and controls the coolant isolation valve. (See Sections 3.1.2 - 3.1.4.)
WATER switch	This switch opens and closes the feedwater shutoff valve, controlling water flow to the sublimator. The WATER switch should be in the ON position, allowing water to flow to the sublimator, only at vacuum. (See Section 3.1.4.)

Component	Description
DISPL (display) switch	This switch allows the crewmember to interact with the DCM display. It is labeled PROC/YES - STATUS/NO. The momentary switch is spring loaded in both positions. Cycling to the PROC/YES position accepts a CWS request to perform a programmed leak check, acknowledges fault messages when first displayed, takes the user through a listing of any fault messages, and takes the user to the beginning of the status list. Cycling to the STATUS/NO position takes the user through a list of monitored EMU parameters (status list), declines to perform a programmed leak check, and declines the option of paging through a list of fault messages. (See Section 3.3)
O_2 actuator	This allows the crewmember to control the operation of the primary oxygen system and SOP. The switch has four positions labeled IV, OFF, PRESS, and EVA. The labeling letters are reversed on the TMG so that the crewmember can read them by using a wrist mirror. (See Section 3.1.1)

3.5 Caution and Warning System

The EMU CWS (I150) monitors the performance of EMU systems. Its functions include:

a. Receives and processes EMU data from the PLSS, SOP, and DCM.

b. Displays EMU status on the DCM display.

c. Detects faults and anomalies in EMU systems and shows them on the display.

d. Sends control signals to the SSER to generate audible tones.

e. Calculates usage rates and time left for EMU consumables.

f. Sends sensor and calculated data to the RTDS for downlink to MCC.

g. Performs CWS self-health checks and indicates CWS health on display.

h. Performs automated leak check during depress.

i. Determines mission profile (X-state) of the EMU.

The components of the CWS include:

a. Microprocessor

b. Memory–Erasable Programmable Read-Only Memory (EPROM, 32Kbyte), Random Access Memory (RAM, 1Kbyte), and Non-Volatile RAM (NVRAM, 1Kbyte)

c. Analog and discrete data acquisition circuits

d. Built-In Test Equipment (BITE)

e. Serial data communications circuits

f. Twelve-character alphanumeric display

Tables 3-9 to 3-17 in this section provide specific information about the EMU CWS.

The microprocessor controls CWS functions and processes data. The EPROM contains instructions that tell the CWS how to operate, and the RAM stores data acquired from the sensors and calculated in the microprocessor. RAM loses its data if power is interrupted, but the NVRAM retains its information for at least 1 minute of power interruption. BITE circuitry continually operates in the background to verify proper CWS operation. Serial data communications circuits send information from the CWS to other EMU systems to control those systems and provide EMU data to the crewmember and MCC.

The CWS monitors EMU functions by scanning EMU test points six times each second. Table 3-16 lists the parameters monitored by the CWS. With each scan, the CWS determines the location of the EMU in the mission timeline and compares the value of each parameter to limits set by the suit configuration. If a failure or an operating sequencing error is detected, the CWS

displays the appropriate fault message and signals an audible tone. The CWS also directs the crewmember to reconfigure the EMU by issuing instruction messages on the DCM display until the EMU is in a safe configuration.

The data acquired comes in several forms, including:

a. dc power

b. Battery parameters

c. Analog sensor data from transducers

d. Motor tachometer data

e. Discrete signals indicating switch positions and vent flow sensor position

The CWS uses the data in many ways. One way is to determine the EMU's mission profile. The EMU has seven separate operating modes, called X-states. As the EVA mission progresses, the CWS automatically transitions to the appropriate X-state based on suit configuration and environment. During a nominal mission, the X-state increments sequentially. Based on X-state, the CWS determines failure conditions (limits) and messages to be displayed. Table 3-9 describes the X-states, and Table 3-10 lists X-state transition events and the conditions for that transition. (There is no X-state 3.)

Table 3-9. X-state descriptions

X-state*	Operating mode
1	Stowage and EMU donning operations
2	EMU donned/IV operations
4	Start of airlock depress
5	Airlock pressure below 4.2 psia
6	Completion of airlock depress
7	EVA operations
8	Airlock repress

*X-state 3 does not exist.

Table 3-10. X-state transition conditions

Current X-state	Next X-state	Conditions
Any state	1	• O2 ACT = OFF • FAN = 0FF • PWR RESTART
1 → (Unmanned)	2	• FAN = ON • O2 ACT = IV
	4	• AIRLK P < 7.5 PSIA or AIRLK ΔP↓≥ 0.5 PSIA
	7	• O2 ACT = EVA • WATER = ON • WATER TEMP <60°F
	8	• AIRLK ΔP↑ ≥0.5 PSIA
2 → (Manned)	4	• AIRLK P <7.5 PSIA or • AIRLK ΔP↓ ≥0.5 PSIA
	7	• O2 ACT = EVA • WATER = ON • WATER TEMP <60°F
	8	• AIRLK ΔP↑ ≥0.5 PSIA
4 → (Depress)	5	• AIRLK P <4.2 PSIA
	7	• O2 ACT = EVA • WATER = ON • WATER TEMP <60°F
	8	• AIRLK ΔP↑ ≥0.5 PSIA
5 → (Depress)	6	• AIRLK P <1.0 PSIA
	7	• O2 ACT = EVA • WATER = ON • WATER TEMP <60°F
	8	• AIRLK ΔP↑ ≥0.5 PSIA
6 → (Depress)	7	• WATER = ON • AIRLK ΔP↑ = 0 OR • X = 6 FOR 4 MIN OR • O2 ACT = EVA • WATER = ON • WATER TEMP <60°F
	8	• AIRLK ΔP↑ ≥0.5 PSIA
7 → (EVA)	8	• O2 ACT ≠ EVA • WATER = OFF OR • WATER = OFF • O2 ACT = EVA • AIRLK P > 1.45 PSIA after AIRLK P <1.0 PSIA
8 → (Repress)	7	• O2 ACT = EVA • WATER = ON • WATER TEMP <60°F
	4	• AIRLK ΔP↓≥0.5 PSIA

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The crewmember interfaces with the CWS through the following items:

a. DCM display

b. BITE light

c. DISPL switch

d. SSER - Status, alert, and warning tones

On the DCM display, the CWS generates status and anomaly messages that the crewmember can read. Only one message can be displayed at once. During nominal EMU operations, the CWS generates a list of current suit status items called the status list. The status list is accessed to monitor current EMU conditions. The data of the status list vary, depending on the conditions in the airlock, the operations being performed, and the position of the power mode switch. Table 3-11 describes items in the status list, and Table 3-12 lists the contents of the status list for each power mode switch position.

Table 3-11. Status list item descriptions

Status list item	Unit/position
O_2 actuator position	OFF, IV, PRESS, EVA
Airlock pressure	psia
Leak check request	—
Elapsed EVA time	hr:min
EVA time remaining/ limiting consumable	hr:min
O_2 remaining	percent
Battery power remaining	percent
Suit pressure	psid
Primary O_2 pressure	psia
Secondary O_2 pressure	psia
Sublimator pressure	psid
Battery voltage	volts (dc)
Battery amperage	amps
Fan speed	rpm
CO_2 partial pressure	mm Hg
Water temperature	°F
Water reservoir gas pressure	psid
Water reservoir water pressure	psid
End of status message	—

Table 3-12. Status list messages

Vehicle power		**Battery power**	
AIRLK P __._ **or** O2 POS _____	**(1)**	AIRLK P __._ **or** O2 POS _____	**(1)**
LEAK CHECK? **or** AIRLK P __._	**(2)**	LEAK CHECK? **or** AIRLK P __._	**(2)**
SUIT P _._		TIME EV __:__	
O2 P ___		TIME LF __:__; ___ % PWR LF	**(3)**
SOP P ___0		; ___ % O2 LF	
SUBLM P __._	**(6)**	; RESRV H2O ON	
BAT VDC __._		; SOP O2 ON	**(4)**
BAT AMP __._		___ % O2 LF	**(5)**
RPM __._ K		___ % PWR LF	
CO2 __._ MM		SUIT P _._	
H2O TEMP __		O2 P ___	
H2O GP __._; H2O WP __._		SOP P ___0	**(6)**
END STATUS		SUBLM P __._	
		BAT VDC __._	
		BAT AMP __._	
		RPM __._ K	
		CO2 __._ MM	
		H2O TEMP __	
		H2O GP __._ ; H2O WP __._	
		END STATUS	

Notes:

(1) If X-state is 7 (EVA), the airlock pressure is changing, or the leak check is being performed; the oxygen actuator position is displayed; otherwise, the airlock pressure is displayed.

(2) This message is displayed only if the X-state is 2 or 4. If the leak check is already being performed, the airlock message is displayed; otherwise, the leak check question is displayed.

(3) This two-line message indicates the limiting consumable. The second line is one of the following:

___ % PWR LF	RESRV H2O ON
___ % O2 LF	SOP O2 ON

(4) This message is displayed only if oxygen is not the limiting consumable.

(5) This message is displayed only if power is not the limiting consumable.

(6) This message is displayed only if X-state is 7 (EVA).

When an out-of-limits condition is detected, the CWS issues a fault message and a warning tone. To prevent interference if multiple faults are detected and to control the order in which multiple messages are displayed, each fault message is assigned a priority rating. The message with the highest priority is displayed first, along with any corrective action to be performed by the crewmember. Lower priority failures are then displayed. All fault messages with their priority numbers and conditions are listed at the end of Section 3.5.

Default messages automatically appear when the display is not showing fault messages or status list items. The default message will be one shown in Table 3-13:

Table 3-13. Default messages

Message	Conditions
AIRLK P __._	Displayed when the airlock pressure is changing
O2 POS _____	Displayed when the airlock pressure is not changing
"BLANK"	Display blank when X-state is 7
SOP O2 ON TIME LF __:__	Displayed when SOP is ON and TIME LF <5 minutes
PWR RESTART	Displayed for 5 sec after powerup or power cycle

In addition to displaying messages, the alphanumeric display can provide visual notification of a CWS failure via the BITE indicator, or BITE light. This asterisk-like figure appears at the far right side of the LCD and is nominally displayed for 4 seconds after powerup or power cycle while the BITE is initialized. The BITE light is off at all other times unless the BITE circuitry detects a problem in the CWS. If the BITE indicator is displayed, parameters displayed by the CWS can be considered unreliable.

The DISPL switch, described in Section 3.4, has two positions. Pressing it to the STATUS/NO position displays the status list one item at a time. If an item in the status list is displayed for more than 20 seconds, the display returns to the default message. Pressing the DISPL switch to the STATUS/NO position again returns the display to the last status list message displayed. When looking at the status list parameters, if the switch is pressed to the PROC/YES position, the display returns to the default message. If the switch is then cycled to STATUS/NO, the first item in the status list is displayed.

When a fault message appears, pressing the switch to the PROC/YES position acknowledges the message and stops the warning tone. The message remains on the display for 20 seconds. The message then goes into the fault stack (in NVRAM), where it remains until the fault goes away (except for RLF V FAIL and LIMITS BAD), or a cold restart of the EMU is performed (FAN OFF, O_2 actuator OFF, power interrupted). Depressing the DISPL switch to the PROC/YES position accesses the fault stack. When the stack is accessed, each fault message in the stack is displayed in order of priority, for 4 seconds per line.

The SSER generates status, alert, and warning tones when the CWS sends control signals to do so. Table 3-14 describes these tones.

Table 3-14. EMU CWS tones

Tone	Type	Duration	When activated
Status	Single frequency	5 sec	Failed leak check
			SOP time left <6 min
Alert	Single frequency	0.5 sec	Position O_2 actuator for leak check
			Successful leak check
			Airlock P = 6.0 psia during depress
			Airlock P = 4.0 psia during repress
			Airlock depress or repress is starting or stopping
Warning	Warbling	Variable	BITE circuitry activated (nominal 4 sec)
			Fault message displayed on DCM (Duration 5 min unless DISPL switch pressed to PROC position OR anomaly disappears)

Another function of the CWS is to lead the crewmember through an automated leak check. This is the only available programmed sequence provided by the CWS, and the EMU must be in X-state 2 or 4. The system performs a 1-minute check to determine whether a leak rate greater than 0.3 psi/min is present in the EMU. It is nominally performed twice: once after EMU donning and once during airlock depress when airlock pressure is 5.0 psia. A typical leak check sequence during EVA PREP proceeds as follows:

Event	Action
1	The crewmember cycles the DISPL switch to STATUS/NO until the message LEAK CHECK? appears.
2	The crewmember cycles the DISPL switch to PROC/YES to start the procedure.
3	SET O2 PRESS appears.
4	The crewmember moves the O_2 actuator to the PRESS position.
5	The suit pressurizes.
6	When the suit is pressurized, SET O2 IV appears and an alert tone is sounded.
7	The crewmember moves the O_2 actuator to the IV position. (IV is used so that the primary O_2 system does not continue regulating suit pressure to 4.3 psid. OFF is not used because the low mode relief valve would open, venting the O_2 behind the water bladders into the suit, invalidating the leak check.)
8	LEAK CHECK-WAIT and SUIT P _._ alternate on the display while the CWS allows 1 minute to check leakage.
9	If the leak check is successful, LEAK CK COMP appears and an alert tone is sounded. Depending on suit and airlock pressure, O2 IS IV, SET O2 PRESS, or SET O2 EVA also appear.
10	If the leak check fails, +LEAKAGE HI and SUIT P _._ appear and a status tone is sounded.

If a crewmember does any one of these actions, the leak check sequence will abort:

1. Actuates the DISPL switch to the PROC/YES position during the leak check (LEAK CHECK? reappears).
2. Presses the O_2 actuator when it is in IV and LEAK CK-WAIT is displayed (LEAK CHECK? reappears).
3. Pauses the O_2 actuator in OFF for more than 5 seconds when moving the actuator in either direction between the IV and PRESS positions during the leak check procedure (this gives an O2 IS OFF fault message, causing condition 2 below)

Two other conditions cause a leak check to abort:

1. The X-state changes to an invalid state for the sequence.
2. If any higher priority messages (i.e., fault messages) appear, except for status list items (status list items can be displayed without aborting the leak check sequence).

If any of these conditions causes the leak check sequence to abort, the crewmember must reinitiate the leak check sequence from the beginning in order to perform the leak check.

During an EVA, the CWS constantly monitors EMU consumables (see Table 3-15). Primary O_2, secondary O_2, and electrical power are directly monitored, and feedwater and the CCC are indirectly monitored. Nominally, the CWS monitors O_2 and power use to determine which one is the limiting consumable and displays it in the limiting consumable slot in the status list (either the XXX% O2 or XXX% PWR message, which alternates with the TIME LF XX:XX message). Power is always the default limiting consumable at the beginning of the EVA. The CWS determines the limiting consumable based on consumption rates and not the amount of consumable left at any particular time. However, if the SOP is on, then it is the limiting consumable. Otherwise, the limiting consumable is the one with the least amount of time remaining.

Table 3-15. EMU limiting consumable parameters

Consumable	Parameters estimated		
Primary oxygen	Use rate	Time left	Percent left
Secondary oxygen	Use rate	Time left	
Battery power	Power left	Time left	Percent left
Water		Time left (timer only)	

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The following describes the consumables monitored directly or indirectly by the CWS.

Consumable	Description
Oxygen	The O_2 use rate, percent O_2 left, and time left are calculated each minute. O_2 time left is displayed in the TIME LF XX:XX message of the status display if oxygen is the limiting consumable.
Electrical power	The percent power left is also calculated each minute. As with the O_2 limiting consumable, the CWS also calculates and displays a time left corresponding to the percent power left. Power time left is displayed in the TIME LF XX:XX slot of the status display if power is the limiting consumable.
SOP	If the SOP is on, it is the limiting consumable, and SOP time left is displayed in the SOP O2 ON/TIME LF:XX fault message. When the TIME LF:XX message is first displayed, it defaults to 30 min time left; however, it is updated every 15 sec as the CWS calculates the actual time left. SOP time left is based on the sum of the mass quantities available from both the SOP and primary O_2 tanks. The total mass available is divided by the mass flow rate to determine the time available. In addition to SOP time left, the CWS calculates and displays SOP rate. The SOP rate is calculated once per minute and is based on SOP pressure readings over time.
Feedwater	The EMU CWS does not calculate the water consumption. It relies on the feedwater tanks' water pressure (Water/Water pressure, or WP) and gas pressure (Water/Gas pressure, or GP) sensor readings to determine whether the primary water tanks are depleted. Whenever the difference between GP and WP is greater than 2.1 psid (GP - WP >2.1 psid), the CWS issues a fault message that the reserve water is on line and that a 30-min-to-end-of-EVA clock has been initiated. Time left starts at 30 min and decreases in 1-min intervals. The clock is simply a timer; actual time left is not calculated.
CCC	The CCC also is a consumable item, but the CWS does not monitor it directly. If the CWS detects vent loop CO_2 concentrations between 3.0 and 8.0 mmHg, a fault message is issued alerting the crewmember that the CCC may be failing.

Table 3-16 lists the data parameters monitored by CWS. Table 3-17 lists the priority messages and conditions.

Table 3-16. Data parameters monitored by CWS

Data type	Parameter	Sensor type	Range
Analog	Primary O_2 tank pressure	Pressure sensor	0 to 1100 ± 27.5 psia
	Suit pressure	Pressure sensor	0 to 6 ± 0.15 psid
	Sublimator feedwater	Pressure sensor	0 to 16 ± 0.4 psia
	H_2O reservoir O_2 pressure	Pressure sensor	0 to 40 ± 1.0 psia
	H_2O reservoir H_2O pressure	Pressure sensor	0 to 40 ± 1.0 psia
	SOP O_2 tank pressure	Pressure sensor	0 to 7400 ± 259 psia
	CO_2 partial pressure	CO_2 sensor	0.1 to 30 ± 2.0 mmHg
	Sublimator outlet temperature	Temperature sensor	32 to 104 ± 1.5°F
	Battery voltage	BATT: voltage	Analog 0 to 25 ± 0.6 V dc
	Battery current	BATT: voltage (1)	Analog 0 to 10 ± 0.3 amps
Discrete	PRO/STATUS in PRO	PRSW: voltage	Discrete
	PRO/STATUS in STATUS	STSW: voltage	Discrete
	Power switch in BATT	BATT: voltage	Discrete
	Power switch in SCU	SCU: voltage	Discrete
	Feedwater valve switch	SUBL: voltage	Discrete
	Ventilation flow	Vent flow switch	3.7 to 5.4 CFM: switch point
	Fan/pump motor	FAN: voltage	Discrete
	O_2 actuator position	OFF/PRESS: voltage (2)	Discrete
	O_2 actuator position	IV/PRESS: voltage (2)	Discrete
	O_2 actuator position	EVA: voltage	Discrete
Tach	Motor RPM	Motor tach: frequency	0 to 25,000 RPM ± 100 RPM

(1) The voltage across a 0.016-ohm resistor is used to determine the current draw from the system.

(2) Three switches set the state of two inputs to the CWS.

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Table 3-17. Priority messages and conditions

Primary message		Secondary message		X-states	Conditions
1	LIMITS BAD	85	LIMITS BAD	1,2,4,5,6,7,8	FAILED LIMITS CHECKSUM (BIT1 - BITE STATUS WORD)
3	BATT AMPS HI SET O2 EVA	81	BATT AMPS HI SET O2 EVA	1,2,4,5,6,7,8	PWR-BATT BATT AMPS >5 FOR 5 SEC O2 ACT ≠ EVA
4	BATT AMPS HI BAT AMPS__.__ BAT VDC __.__	82	BATT AMPS HI BAT AMPS __.__ BAT VDC __.__	1,2,4,5,6,7,8	PWR-BATT BATT AMPS >5 FOR >5 SEC O2 ACT = EVA
5	BATT VDC LOW BAT VDC __.__	83	BATT VDC LOW BAT VDC __.__	1,2,4,5,6,7,8	PWR-BATT BATT VOLTS <15.7 VDC BATT AMPS ≤5.0 or >5.0 FOR <5 SEC
6	SUIT P LOW SUIT P __.__	60	SUIT P __.__	1,2,4,5,6,7,8	O2 ACT = EVA 3.2 ≤SUIT P ≤4.05 PSIG SOP RATE <24 PSID/MIN
7	SUIT P LOW SET O2 EVA	60	SUIT P __.__	1,2,4,6,8	O2 ACT ≠ EVA SUIT P + AIRLK P <4.05 PSIA
7	SUIT P LOW SET O2 EVA	60	SUIT P __.__	7	O2 ACT ≠ EVA SUIT P <4.05 PSIA
8	SUIT P EMERG CLOSE PURG V	60	SUIT P __.__	5,6,7,8	O2 ACT = EVA SUIT P <3.1 PSIG
9	SOP O2 ON TIME LF __:__	71	SOP O2 ON TIME LF __:__	1,2,4	O2 ACT = EVA SUIT P <3.1 PSIG
9	SOP O2 ON TIME LF __:__	71	SOP O2 ON TIME LF __:__	5,6,7,8	O2 ACT = EVA 3.2 ≤ SUIT P <4.05 PSIG SOP RATE >36PSID/MIN
10	SUIT P LOW REPRES AIRLK	60	SUIT P __.__	5	O2 ACT ≠ EVA SUIT P <4.05 PSIG
11	RLF V FAIL STOP DEPRESS	60	SUIT P __.__	1,2,4,5,6,7,8	SUIT P >5.7 PSIG
12	SUIT P HIGH O2 RATE __.__ SOP RATE ____	60	SUIT P __.__	7	4.55 <SUIT P ≤5.7 PSIG FOR ≥10 MINS AFTER X = 7 SUIT PRESSURE HAS NEVER BEEN >5.7 PSIG SINCE COLD START
12	SUIT P HIGH O2 RATE __.__ SOP RATE ____	60	SUIT P __.__	8	4.55 <SUIT P ≤5.7 PSIG SUIT PRESSURE HAS NEVER BEEN >5.7 PSIG SINCE COLD START
12	SUIT P HIGH O2 RATE __.__ SOP RATE ____	60	SUIT P __.__	1,2	4.55 <SUIT P ≤5.7 PSIG FOR ≥30 SEC SUIT PRESSURE HAS NEVER BEEN >5.7 PSIG SINCE COLD START

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Table 3-17. Priority messages and conditions (continued)

Primary message		Secondary message		X-states	Conditions
13	O2 USE HIGH O2 RATE __.__	65	O2 USE HIGH O2 RATE __.__	1,2,4,5,6,7	O2 RATE >10.2 PSID/MIN VEHICLE VOLTS NOT SENSED
13	O2 USE HIGH O2 RATE __.__	65	O2 USE HIGH O2 RATE __.__	1,2,4,5,6,7,	TIME EVA > 5 HR O2 RATE > 10.2 PSID/MIN VEHICLE VOLTS NOT SENSED
13	O2 USE HIGH O2 RATE __.__	65	O2 USE HIGH O2 RATE __.	1,2,4,5,6,7,	PRIM O2 P <150 PSIA TIME EVA <5 HR VEHICLE VOLTS NOT SENSED
14	SOP P LOW SOP P____O SOP RATE ____	74	SOP P LOW SOP P____O SOP RATE _____	1,2,4,5,6,7,8	SOP P <INIT SOP P - 600
16	NO VENT FLOW SET O2 EVA	64	NO VENT FLOW	6,7	O2 ACT ≠ EVA SOP RATE ≤ 36 PSID/MIN O2 RATE <24 PSID/MIN FAN = ON VENT CLOSED FOR >7 SEC
17	NO VENT FLOW	64	NO VENT FLOW	1,2,4,5,8	O2 RATE <24 PSID/MIN SOP RATE ≤36 PSID/MIN FAN = ON VENT CLOSED FOR >7 SEC
17	NO VENT FLOW	64	NO VENT FLOW	6,7	O2 RATE <24 PSID/MIN SOP RATE ≤36 PSID/MIN FAN = ON O2 ACT = EVA VENT CLOSED FOR >7 SEC
20	FAN SW OFF	66	FAN SW OFF	2,4,5,6,7,8	SOP RATE ≤36 PSI/MIN O2 RATE <24 PSI/MIN FAN = OFF SUIT P >0.25 PSIG
21	VENT SW FAIL	76	VENT SW FAIL	1,2,4,5,6,7,8	SOP RATE ≤36 PSID/MIN O2 RATE <24 PSID/MIN FAN = OFF VENT OPEN FOR >7 SEC.
23	CO2 HIGH DOFF EMU	62	CO2 HIGH	2,4,5,8	CO2 >8.0 mmHg AIRLK P > .5 PSIA
24	CO2 HIGH SET O2 EVA	62	CO2 HIGH	6,7	CO2 >8.0 mmHg O2 ACT ≠ EVA
25	CO2 HIGH OPEN PURGE V	62	CO2 HIGH	6,7	CO2 >8.0 mmHg O2 ACT = EVA

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Table 3-17. Priority messages and conditions (continued)

Primary message		Secondary message		X-states	Conditions
26	CO2 HIGH REPRES AIRLK	62	CO2 HIGH	2,4,5,8	CO2 >8.0 MMHG AIRLK P <7.3 PSIA
29	SET O2 EVA	61	SET O2 EVA	5,6,7	O2 ACT ≠ EVA
30	SET O2 PRESS	84	SET O2 PRESS	8	SOP RATE ≤ 36 PSID/MIN O2 ACT ≠ PRESS AIRLK P < 4.0 PSIA
30	SET O2 PRESS	84	SET O2 PRESS	8	SOP RATE ≤ 36 PSID/MIN O2 ACT = EVA
33	SUBLM P __.__ SET H2O OFF	72	SUBLM P __.__	7	SUBLM P > 5.3 PSIA OR SUBLM P < 1.5 PSIA FOR ≥ 15 SEC WATER = ON
36	SET H2O OFF	78	SET H2O OFF	1,2,4,5,6,8	WATER = ON
37	SET PWR SCU	79	SET PWR SCU	1,2,4,5,6,7,8	PWR = BATT VEHICLE VOLTS SENSED FOR >60 SEC BATT AMPS <4.8 OR BATT AMPS >5.0 FOR <5 SEC BATTERY VOLTS >15.9
38	___% O2 LF TIME LF __:__	67	___% O2 LF TIME LF __:__	1,2,4,5,6,7	PWR = BATT CALCULATED TIME LF ≤30 MIN
39	___%PWR LF TIME LF __:__	68	___% PWR LF TIME LF __:__	1,2,4,5,6,7,8	PWR = BATT CALCULATED TIME LF ≤30 MIN
40	CO2__.__MM MONITOR CO2	69	CO2__.__MM MONITOR CO2	2,4,5,6,7,8	3.0 <CO2 <8.0 mmHg
41	RESRV H2O ON TIME LF __:__	70	RESRV H2O ON TIME LF __:__	7,8	PWR = BATT H20 GP-H20 WP >2.1 PSID
44	O2 IS OFF	77	O2 IS OFF	2,4	O2 ACT = OFF FOR ≥5 SEC
44	O2 IS OFF	77	O2 IS OFF	8	O2 POS = OFF FOR >5 SEC 4.2 <AIRLK P <7.3 PSIA
163	SOP O2 ON TIME LF __:__			7,8	3.2 <SUIT P <4.05 PSIG SOP RATE > 6 PSID/MIN TIME LF __:__ <5 MIN

3.6 Contaminant Control Cartridge (CCC)

a. The CCC removes the following from the ventilation circuit:

a. CO_2

b. Odors

c. Particulates

d. Trace contaminants

When ventilation gas returns from the HUT to the PLSS, it first passes through the CCC. As the ventilation gas flows through the cartridge to the fan, beds of chemicals remove CO_2, odors, and contaminants, while filters remove particulates. Two versions of the CCC exist: a lithium hydroxide (LiOH) canister, and a Metal Oxide (Metox) canister. Both serve the same operational function; however, the LiOH canister is used for shuttle-based EVAs, and the Metox canister is used for ISS-based EVAs.

The cartridge is located in a compartment on the back of the PLSS under a TMG flap that unzips to provide access (Figure 3-17). It can be removed and replaced on orbit by a single IV crewmember without tools in less than 5 minutes. The canister can be replaced while a crewmember is in the suit, but the EMU must be in a pressurized environment. The CCC is changed out between successive EVAs.

To replace the CCC in the PLSS, perform the following steps:

1. Unzip and lift the TMG flap on the back of the PLSS.

2. Open the latch on each side of the CCC (Figure 3-18).

3. Rotate the bottom of the canister outboard by pulling the Velcro retention strap.

4. Pull the cartridge down to remove the inlet and outlet ports from the rotating receptacles on the PLSS.

5. Install the new cartridge by inserting the ports into the receptacles (Figure 3-19), rotating the canister into the PLSS, closing the latches, and zipping the TMG shut.

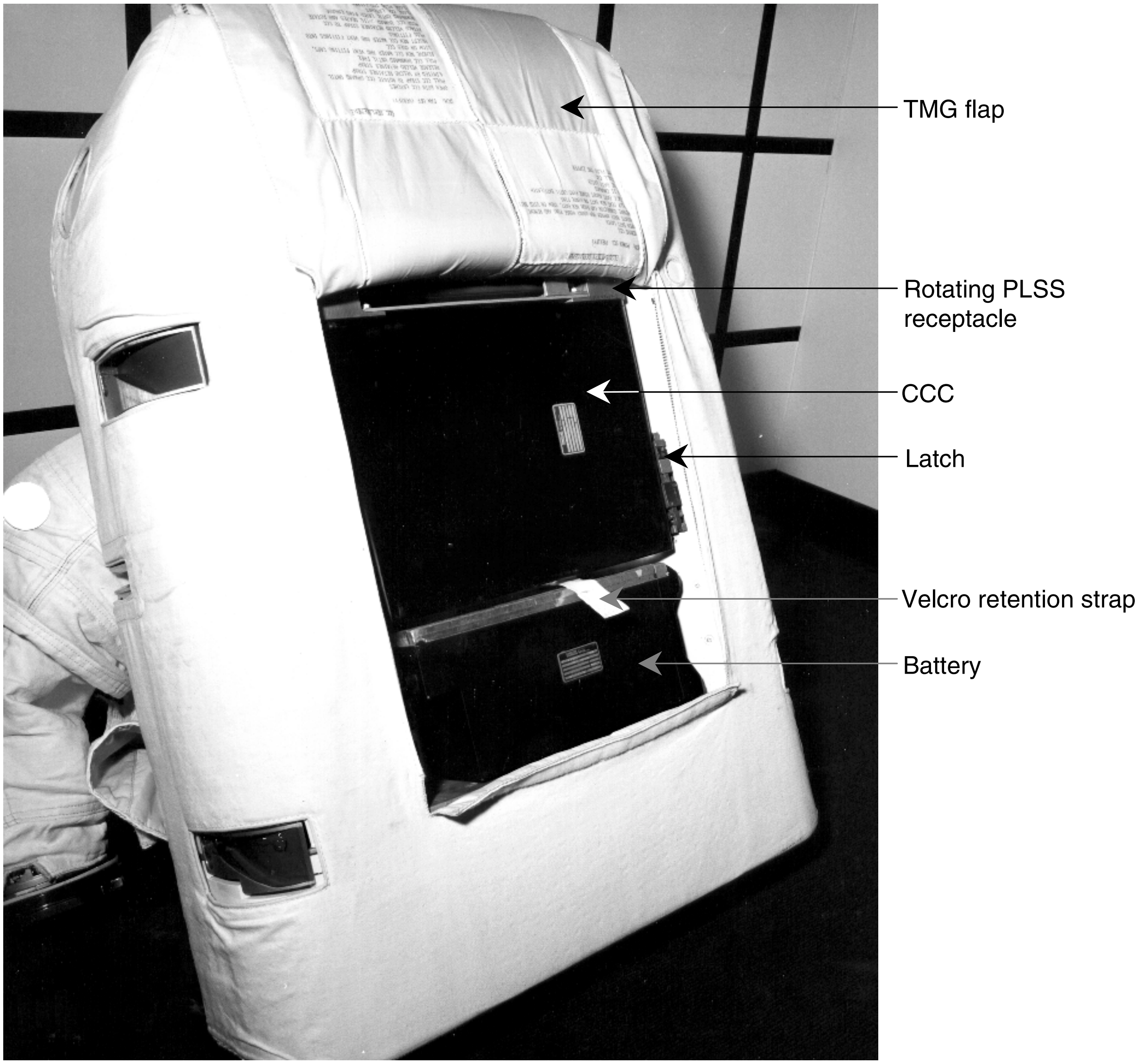

Figure 3-17. CCC location in PLSS

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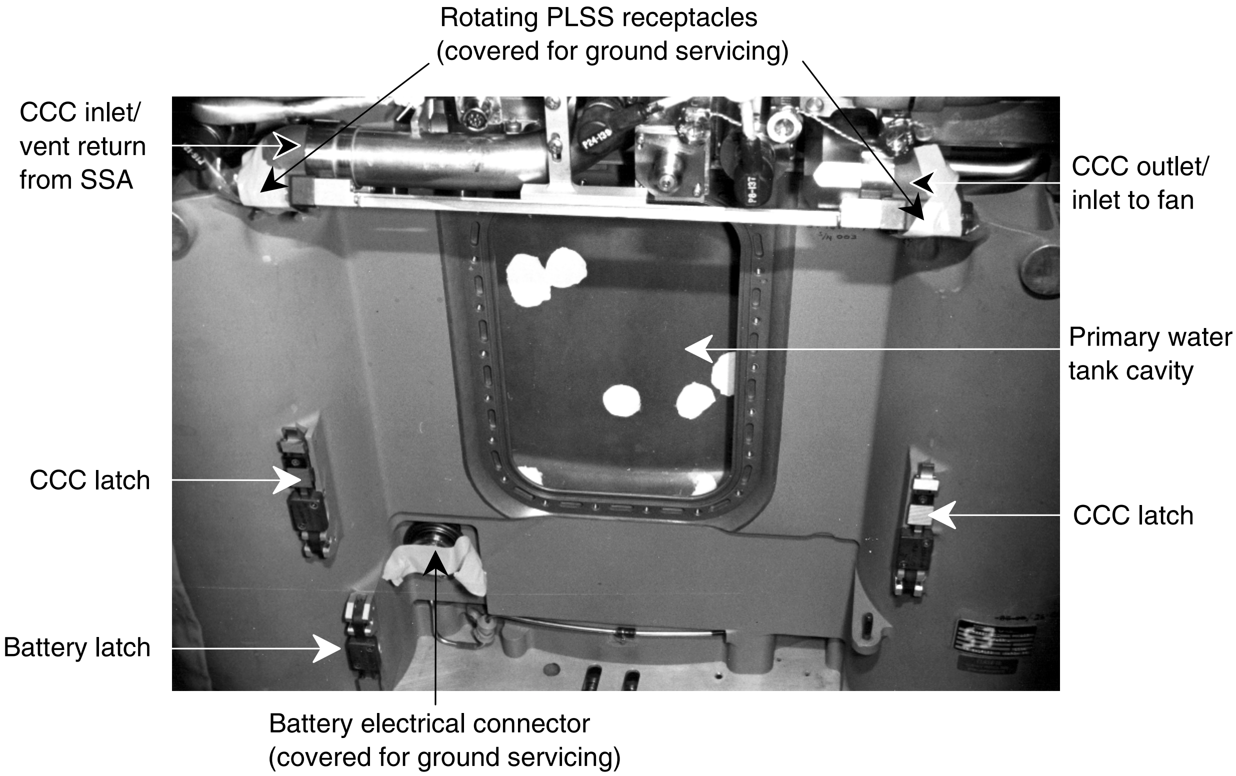

Figure 3-18. PLSS CCC interfaces

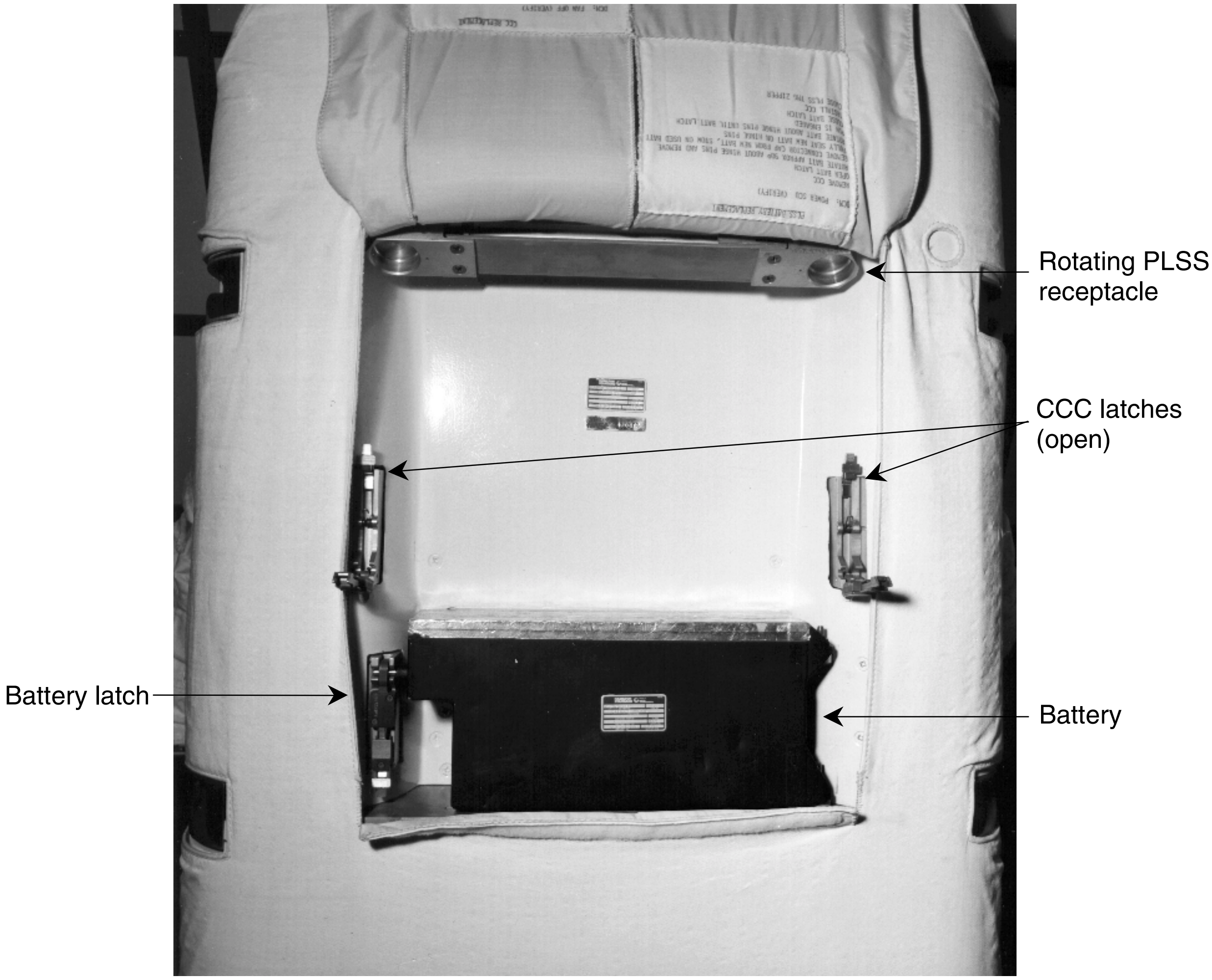

Figure 3-19. CCC installation location

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3.6.1 Lithium Hydroxide (LiOH) Canister

e. The LiOH cartridge (Figures 3-20 and 3-21) is made up of the following components:

a. Canister housing with inlet and outlet ports and latch pins

b. LiOH bed

c. Activated charcoal bed

d. Particulate filter

e. Caps for the canister inlet and outlet ports

f. Aluminum tape over the caps

Table 3-18 lists the LiOH cartridge parameters and values.

Table 3-18. LiOH cartridge parameters

Parameter	Value
CO_2 level normally seen during EVA	0.1 to 0.3 mmHg
Maximum operating pressure (1)	6.7 psig
Leakage (limit) (2)	10 scc/hr (max.) at 6.5 psig
CO_2 removal	1.48 lb (min.)
$ppCO_2$ limits (3)	<7.6 mmHg for 1 hr at 1600 Btu workload <15 mmHg for 15 min at 2000 Btu workload
Capacity (certified minimum)	7000 Btu (7hr EVA at 1000 Btu/hr average workload) plus prebreathe. See Table 3-19
Total cartridge weight	6.4 lb max.
LiOH weight	2.45 lb min.
Charcoal weight	0.121-0.286 lb
Particulate concentration in ventilation flow (max.)	0.1 mg/m^3

(1) BTA operation at 8.45 psig is acceptable because CCC proof pressure is 10.05 psig.
(2) Refers to overboard leakage through the inlet/outlet ports.
(3) Refers to CO_2 limits in helmet area.

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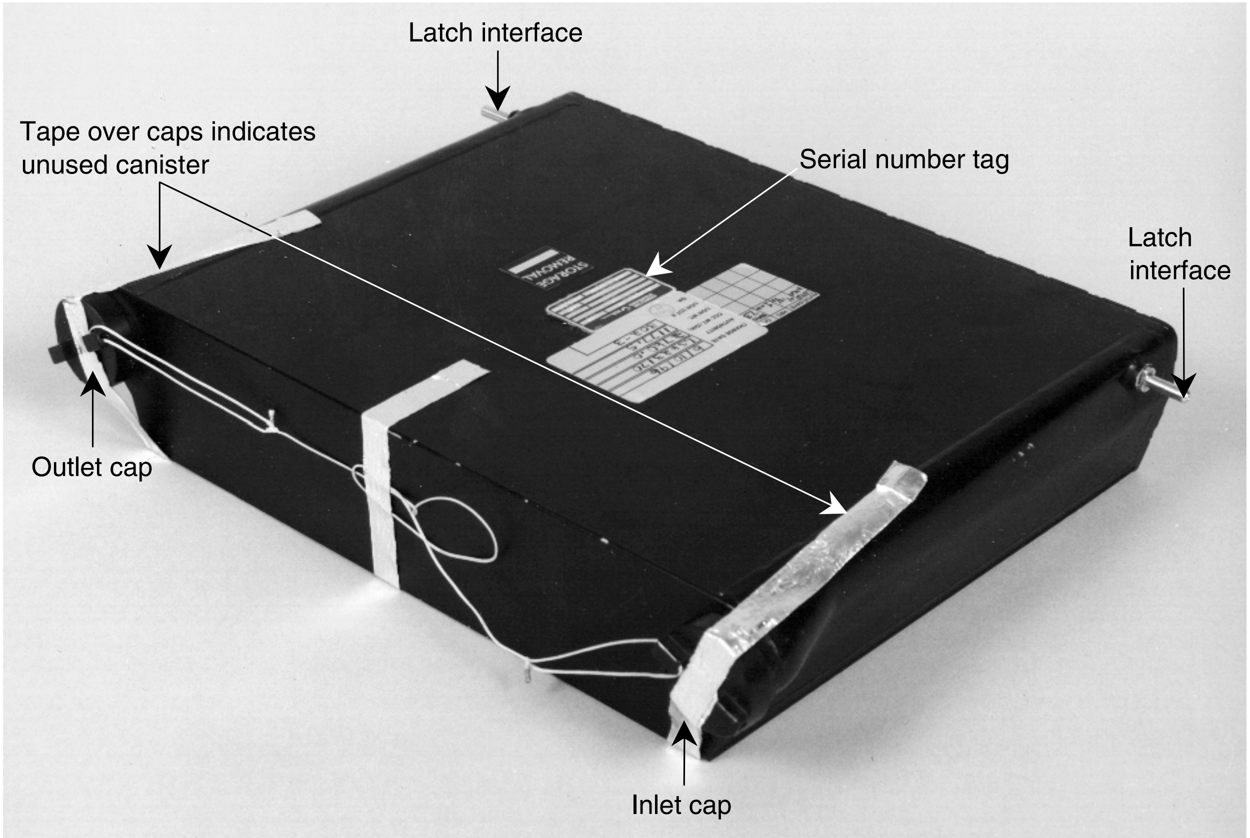

Figure 3-20. LiOH canister

As ventilation gas returns from the HUT to the PLSS, it enters the canister inlet port. In the LiOH canister, the gas passes through a bed of activated charcoal, a bed of LiOH, and the particulate filter. The activated charcoal removes odors and trace contaminants, the LiOH removes CO2, and the filter traps particulate matter. The chemical reaction in the LiOH bed adds heat and water vapor to the ventilation gas. This warm, humid ventilation gas exits the canister through the outlet port and is drawn to the fan.

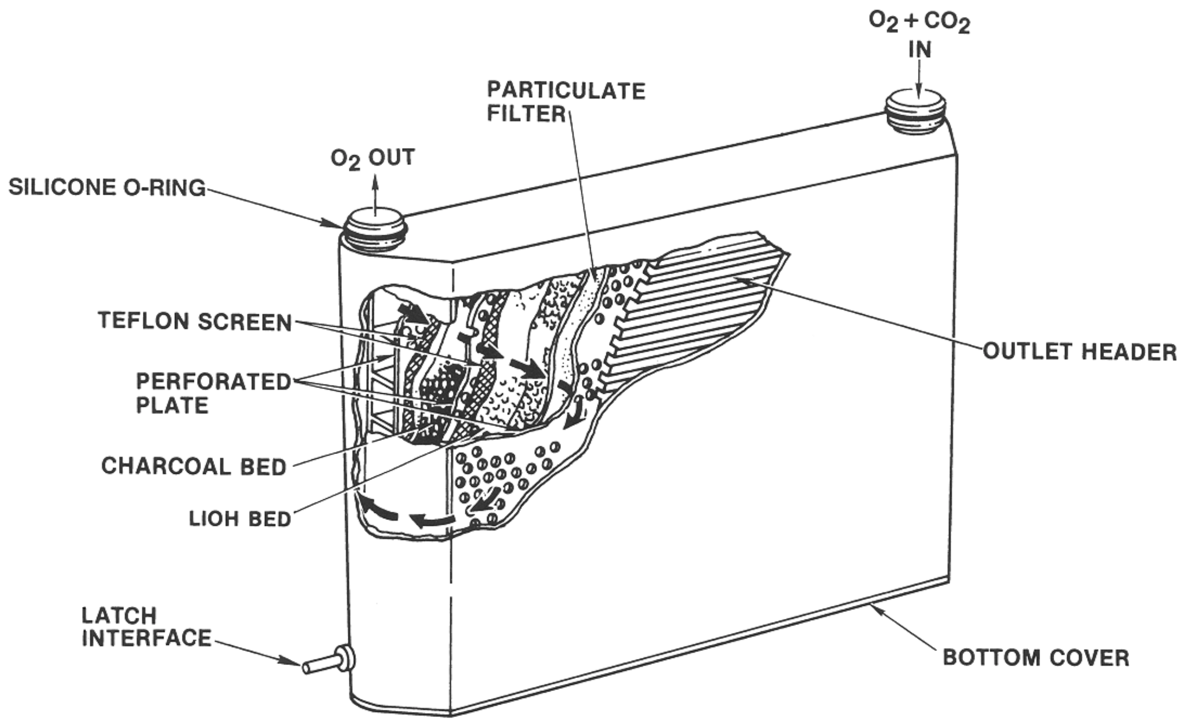

Figure 3-21. Cutaway drawing of LiOH canister

Caps are installed on the inlet and outlet ports when the CCC is not installed in the EMU. Each cap has a small hole in it to allow the pressure in the cartridge to equalize with orbiter pressure. A strip of aluminum tape is placed over the cap during ground servicing. This seals the hole until just before the crewmember installs the CCC into the EMU. Keeping the hole sealed prevents ambient CO_2 from entering the CCC and degrading its capacity for EVA use. The tape also holds the caps on the ports and signifies that the cartridge has not yet been used.

The CO_2 removal capacity of the LiOH is a function of the environment. The capacity of the LiOH is higher in a warm-to-neutral environment than in a cold environment. A cold environment is defined as -75° F or colder. If the orbiter is in a cold attitude, this temperature may be encountered during the EVA.

The LiOH cartridge is certified for a 7-hour EVA after a 4-hour prebreathe, assuming a neutral/hot environment. If the environment is cold, the canister has less capacity. These situations are detailed in Table 3-19.

Table 3-19. LiOH cartridge certification matrix

Prebreathe time	Environment		
	Cold	Neutral	Hot
20 to 40 min	X	X	X
3.5 to 4.0 hr	*	X	X

X - The CCC is qualified to meet the 7-hour (7000 Btu) EVA requirement.
* - For a cold environment, the CCC is qualified to meet a 4.8-hour EVA.

The CO_2 partial pressure that usually exists in the EMU during EVA is between 0.1 to 0.3mmHg. LiOH is usually not the EMU consumable that limits EVA time (usually, the limiting consumable is battery power). However, if a canister's capacity gets used up, the levels of CO_2 in the EMU will gradually increase. When the level reaches 3.0 mmHg, the CWS issues a MONITOR CO2 message on the DCM display. When the level reaches 8.0 mmHg, a CO2 HIGH message is issued. Time for this to occur is approximately 1 hour for levels to climb from 0.3 mmHg to 3.0 mmHg, and then another hour to reach 8.0 mmHg.

A used LiOH cartridge cannot be recharged on orbit for reuse. It can only be serviced on the ground.

3.6.2 Metal Oxide (Metox) Canister

The Metox canister was developed for use on the ISS. It will perform the same function as the LiOH cartridge. The major difference between the two canisters is the chemical used to remove CO_2 from the ventilation gas. The metal oxide used in this canister can be regenerated on orbit, so the canister can be reused for subsequent EVAs. For more information on the Metox canister, contact DX32/EVA Systems personnel or refer to the ISS Joint Airlock Systems Training Manual (JSC-36344).

3.7 EMU Electrical System

The EMU electrical system performs the following functions:

a. Stores electrical power.

b. Distributes electrical power to EMU components.

c. Routes data between the following: sensors, CWS, RTDS, SSER, CCA, OBS, DCM.

The electrical system encompasses the following components:

a. Battery

b. Motor (fan/pump/water separator)

c. CWS

d. RTDS

e. SSER

f. DCM

g. CCA

h. OBS

i. Feedwater shutoff valve

j. Coolant isolation valve

k. Instrumentation

l. Harnesses

Table 3-20 lists the specifications for the EMU electrical system.

Table 3-20. EMU electrical system specifications

Item	Specification
Nominal system voltage	16.5 to 17.0 V
Nominal system current draw	3.8 A
Motor current draw	2.45 A (average)
SSER current draw	0.7 A (average)

SSSH Drawing 21.11 is a schematic of the EMU electrical system. It shows the basic power distribution system and electrical interfaces. Electrical power is supplied by the internal battery, discussed below, or by the vehicle via the SCU. The crewmember determines the power source and supplies power to various EMU components by actuating switches on the DCM. The electrical system harnesses allow the transfer of power and data between the motor, CWS, RTDS, SSER, CCA, OBS and sensors. The component that draws the most current is the motor, which drives the fan, pump, and water separator (Sections 3.1.2 and 3.1.3). Next in order of current draw is the SSER. The other components use smaller amounts of current.

Included in the electrical system are two electrically operated valves: the feedwater shutoff valve and the coolant isolation valve. These latching solenoid valves are contained in the EMU feedwater circuit (Section 3.1.4).

The instrumentation in the electrical system consists of sensors and transducers that monitor critical performance parameters and provide signal inputs to the CWS. The functions of this instrumentation are discussed throughout Section 3.

The battery stores and supplies electrical power for use when the EMU is not receiving vehicle power via the SCU. However, the EMU electrical system does not supply power to the helmet lights or to the heated gloves. Those components have independent power supplies.

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3.7.1 EMU Battery

The function of the EMU Battery is to store and supply electrical power for use when the EMU is not receiving vehicle power via the SCU.

The EMU battery consists of the following components:

a. Eleven sealed cells connected in series

b. Relief valve in each cell

c. Absorbent material

d. Aluminum case

Specifications of the EMU battery are listed in Table 3-21. Refer to Figures 3-22 to 3-26 for illustrations of the battery and its interfaces.

Table 3-21. EMU battery specifications

Description	Specification
Discharge cycle	3.8 A for 7 hr (26.6 A-hr) to a minimum voltage of 16.0 V dc
Nominal operating voltage	16.5 to 17.0 V dc
Weight	9.9 lb max. when activated with electrolyte (wet)
Operational life	6 full charge/discharge cycles in addition to ground processing cycles
Wet life (1)	170 days
Time to recharge	<20 hr after 7-hr EVA use
Charging current (nominal)	1.55 ± 0.05 A
Trickle charge current	<1.0 A
Battery voltage at charge cutoff	21.8 ± 0.1 V
Relief valve - relief pressure	16 to 40 psid
Relief valve - reseat pressure	3 psid (minimum)
Leakage (if relief valves open)	<150 cm^3 H_2 gas; no electrolyte liquid

(1) The battery wet life is defined as the time period, starting when the battery is filled with electrolyte, during which the battery is certified to perform its full operational life.

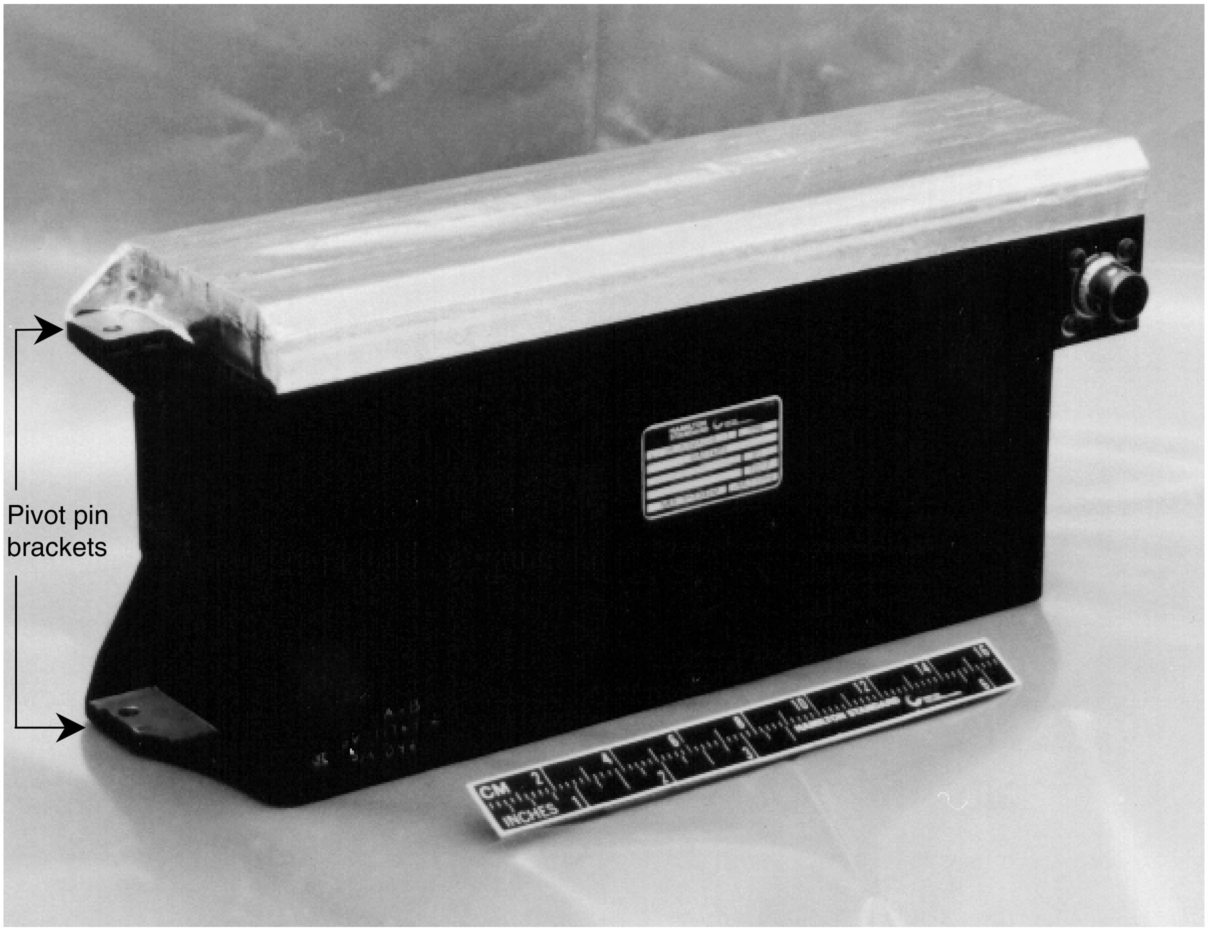

Figure 3-22. EMU battery

When the DCM power switch is in the BATT position, the battery powers the EMU. The battery supplies all EMU electrical power while EVA. To ensure full capacity, the battery charge is topped off at the end of EMU checkout, because some battery power is used during that procedure. The battery is also charged between subsequent EVAs. However, if EVAs are planned on consecutive days, there may not be sufficient time between EVAs to recharge the battery in the EMU because it takes ~14 to 20 hours to charge the battery, depending on the length of the previous EVA. In that case, an extra battery would be topped off in the middeck battery charger (Figure 3-25). The spare would then replace the used battery in the EMU, and the used battery may be recharged in the EMU middeck battery charger.

Each of the battery's 11 sealed cells consists of one silver and one zinc electrode immersed in a potassium hydroxide electrolyte. Each cell also has a two-stage relief valve. This assembly provides a sealed system that serves as a safety mechanism in the event of excessive pressure buildup. It prevents the cell from bursting by allowing electrolyte to escape from the cell. Absorbent wicking material in a cavity behind each relief valve keeps electrolyte from leaking out of the battery. The battery case includes a latch pin, an electrical connector, and hinge brackets that allow installation in the PLSS.

The battery is located in the rear of the PLSS under a TMG flap below the CCC. It can be removed and replaced on orbit by a single IV crewmember without tools in less than 5 minutes. To remove it, first remove the CCC or rotate it out of the way. Then open the battery latch, which is identical to the CCC latches. Next, rotate the battery out and lift up to remove it (Figure 3-23). To install, perform these steps in reverse.

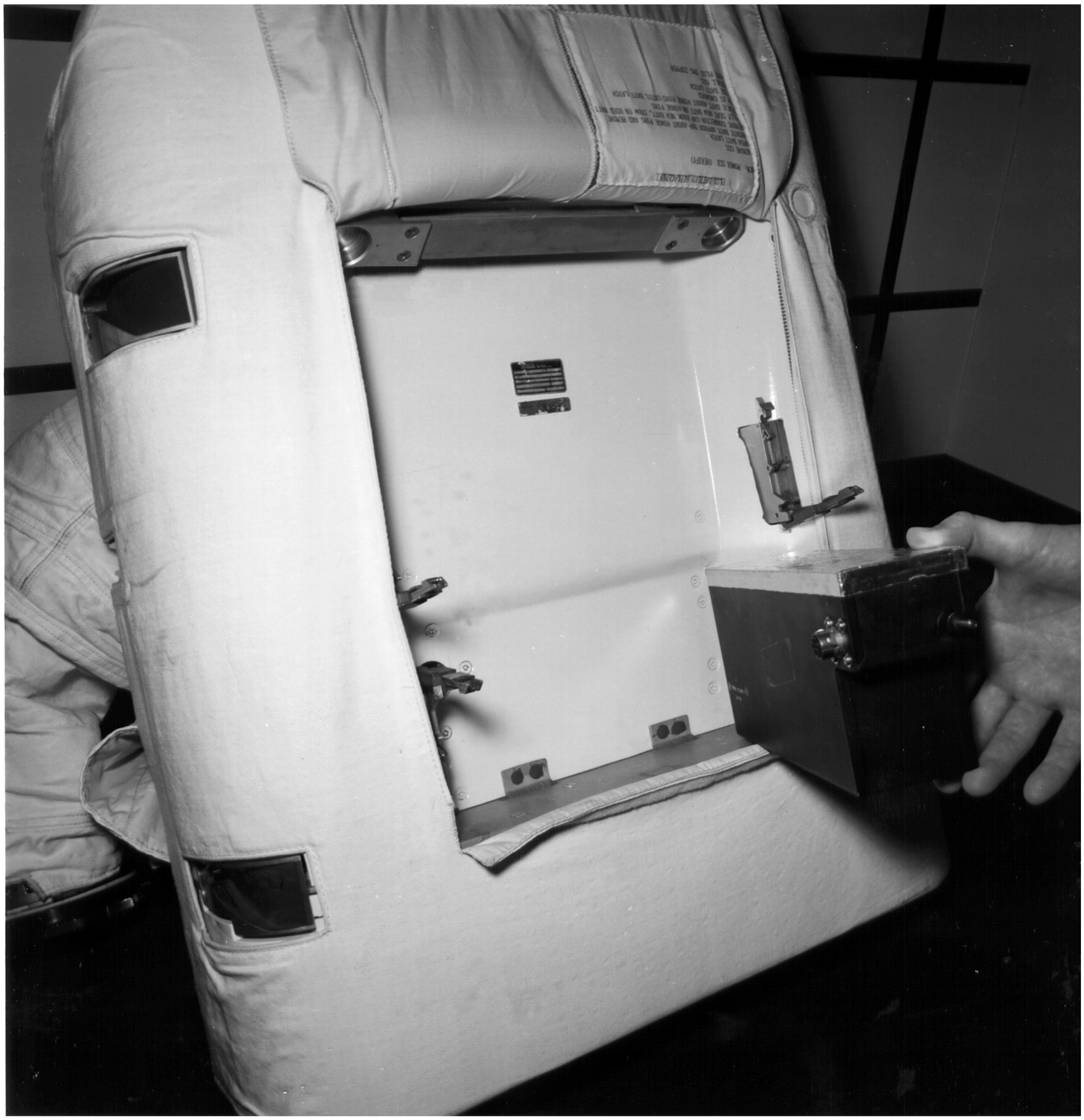

Figure 3-23. Battery rotated out of PLSS compartment

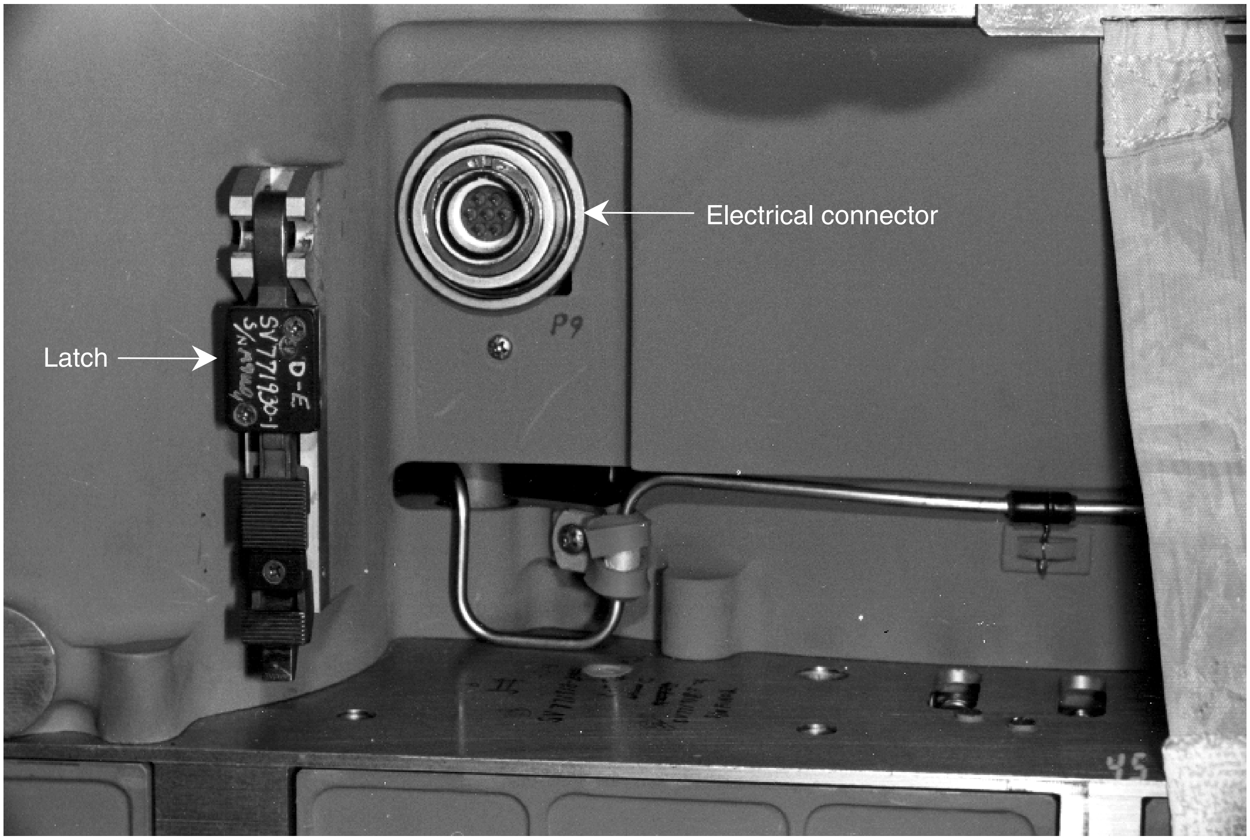

Figure 3-24. PLSS battery latch and electrical connector

On orbit, the battery can be recharged in the EMU via the SCU and Airlock Power Supply (ALPS) or in a middeck battery charger. In the EMU, when the charge is started, the EMU input amps shown on airlock panel AW18H will increase from zero to the nominal charging current. Once the battery is fully charged and has reached the charge cutoff current, EMU input amps will drop and begin a trickle charge. This indicates a fully charged battery. The middeck battery charger indicates that the battery is charging by illuminating a red Light Emitting Diode (LED). When the battery is fully charged, the charge is stopped, the red LED extinguishes, and a green LED illuminates.

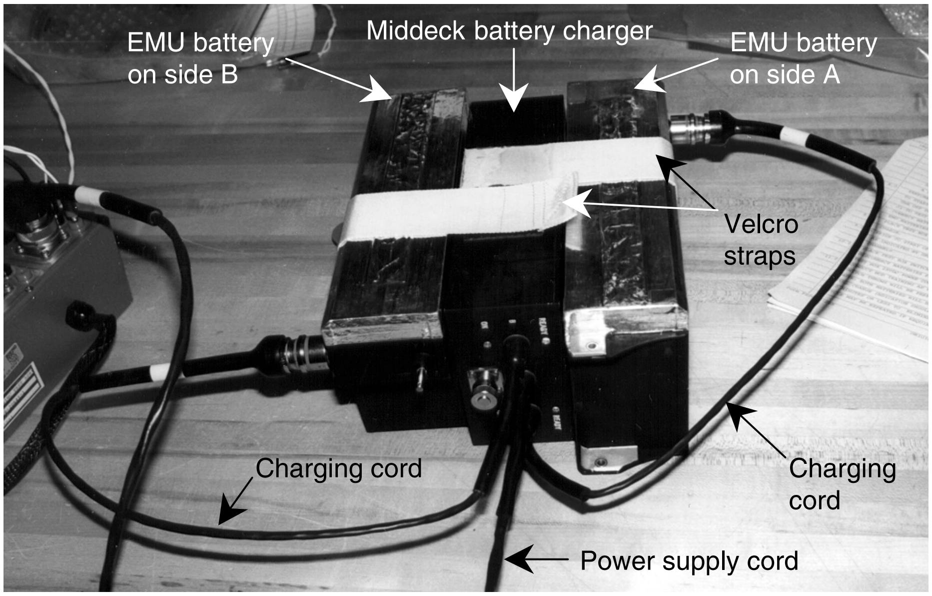

Figure 3-25. Middeck battery charger

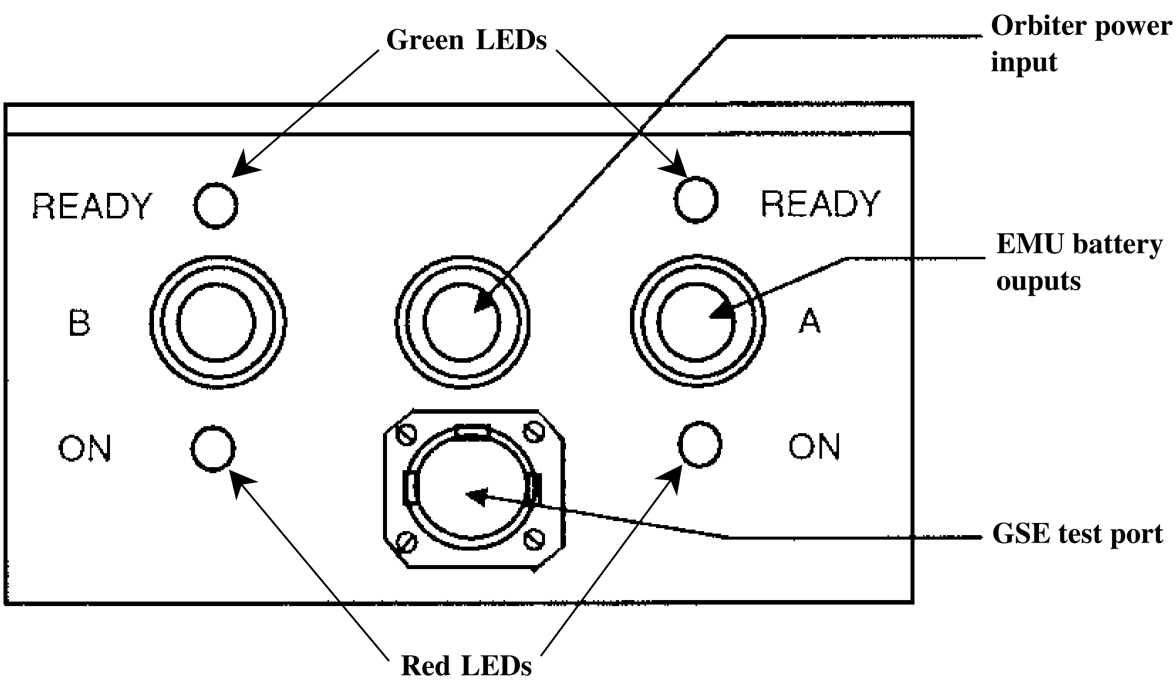

Figure 3-26. Middeck battery charger labels

Battery power is often the consumable that limits EVA time. If the battery gets low during EVA (below 15.7 V dc), the CWS will issue a BATT VDC LOW message on the DCM display. The crewmember may also notice scratchy communications and/or slowing of the fan speed.

3.7.2 EMU Increased Capacity Battery

The EMU Increased Capacity Battery (ICB) is currently being developed for use. It will replace the EMU battery and perform the same operational function. The major difference between the two batteries is that the ICB has a much longer wet life than the EMU battery (Table 3-22). This is necessary to meet stowage requirements onboard ISS.

The longer wet life also reduces operating cost by allowing more operating cycles between ground servicing. This increase in cycles reduces the number of batteries needed to support shuttle and ISS missions. It also reduces the cost of ground processing.

The EMU ICB consists of the following components:

a. Eleven sealed cells connected in series

b. Relief valve in each cell

c. Absorbent material

d. Aluminum case

Table 3-22. EMU ICB comparison

Description	EMU Battery	EMU ICB
Discharge cycle	3.8 A for 7 hr (26.6 A-hr) to a minimum voltage of 16.0 V dc	3.8 A for 7 hr (26.6 A-hr) to a minimum voltage of 16.0 V dc
Nominal operating voltage	16.5 - 17.0 V dc	16.5 to 17.0 V dc
Weight when activated with electrolyte (wet)	9.9 lb max.	14.7 lb
Operational life (full charge/discharge cycles in addition to ground processing cycles)	6	32
Wet life (1)	170 days	425 days
Charging current (nominal)	1.55 ± 0.05 A	1.55 ± 0.05 A
Trickle charge current	<1.0 A	<1.0 A
Battery voltage at charge cutoff	21.8 ± 0.1 V	21.8 ± 0.1 V
Relief valve - relief pressure	16 to 40 psid	32 to 40 psid
Relief valve - reseat pressure	3 psid (min.)	28 psid (min.)
Leakage (if relief valves open)	< 150 cm^3 H_2 gas, no electrolyte liquid	<150 cm^3 H_2 gas; no electrolyte liquid

(1) The battery wet life is defined as the time period, starting when the battery is filled with electrolyte, during which the battery is certified to perform its full operational life.

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The components in the ICB are similar to those in the EMU battery. Changes were made to provide the increased capacity, improve reliability, and ease manufacture. One notable component difference is that the relief valves on the cells are single, not dual stage. This reduces the chance of the worst case failure happening, which is when the relief valve fails closed. If the single stage were to fail open, the absorbent wicking material can absorb the entire electrolyte in the cell. A single stage also has fewer parts to fail, increasing reliability.

The ICB is charged and replaced in the same manner as the EMU battery. Physically, the ICB is about 1 inch deeper than the EMU battery. This additional depth causes it to bulge out of the back of the PLSS slightly.

3.8 PLSS Item Summary

Table 3-23 is a review of the PLSS systems and items.

Table 3-23. PLSS item summary

Item number	Name	Description
	Primary O2 System	Provides self-contained Oxygen for EMU pressurization, Water Tank pressurization, metabolic consumption, and leakage makeup
111	Primary O2 Tanks	The two tanks together are designed to provide enough O2 for a 7-hr EVA (~1.2 lb at 850 psi for 6 hr useful EVA time, 15-min egress, 15-min ingress and a 30-min reserve.). This Oxygen is used for system pressurization, metabolic consumption, and EMU leakage makeup. Oxygen also may be supplied via the Service and Cooling Umbilical (SCU) and refilled in a less than 10 min
112	Primary O2 Pressure Sensor (range: 0 to 1100 +/-27.5psia)	Senses the Primary O2 Tank pressure. The CWS (I150) uses the sensor to provide the O2 P XXX status on the DCM Display (I351) and the messages O2 USE HI, %O2 LF XX, and TIME LF :XX
113	*Primary O2 Pressure Control Module*	
113a	Check Valve	Prevents Primary O2 Tank (I111) backflow through the SCU (I400) to the vehicle if the vehicle's pressure is less than the Primary O2 Tank's; with the SCU disconnected, this valve is redundant with the DCM SCU Interface's (I330) O2 charge poppet in preventing Primary O2 Tank leakage through the EMU O2 fill line
113b	Variable Orifice (Flow Restrictor)	Limits O2 flow from the Primary O2 System to ~7.5 lb/hr in order to prevent overpressurization of the suit in the event of a failed open Suit Pressure Regulator (I113d) or Water Pressure Regulator (I113e). This flow rate is less than the PPRV (I146) maximum flow rate if such an failure occurs
113c	O2 Shutoff Valve	Isolates the Primary O2 Tanks (I111) from the suit and water tanks. Through a mechanical cable linkage, this valve is closed when the 02 Actuator (I115) is in OFF, and open in all other O2 Actuator positions (IV, PRESS, EVA)
113d	Dual Mode Regulator (Suit Pressure Regulator)	Controls suit pressure. Regulates suit pressure to 0.9 ± 0.5 psid above ambient pressure in the IV position for better mobility during IV ops, and to 4.3 ± 0.1 psid above ambient in all other O2 Actuator positions (OFF, PRESS and EVA). NOTE: The difference between EVA and PRESS position of the O2 Actuator is that the SOP (I200) will flow automatically in EVA if the suit pressure drops below ~3.9 psid
113e	Water Pressure Regulator	Controls the pressure of the water tanks. Regulates to 15.15 ± 0.55 psid above ambient to pressurize the backside of the water tank bladders. This pressurizes the Feedwater System to provide proper H2O flow to the Sublimator (I140) and to pressurize the Cooling Loop for proper degassing of the loop

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Table 3-23. PLSS item summary (continued)

Item number	Name	Description
116	EVA Position Switch	Provides indication to the CWS (I150) that the O2 Actuator is in the EVA position. The CWS (I150) uses the sensor to provide the O2 ACT-EVA status on the DCM Display (I351). Physically located at the interface between the PLSS and SOP (I200) above the SOP manual override lever
120	*Dual Mode Relief Valve Module*	
120a	Bleed Orifice	Allows O2 to bleed (at a rate of less than 1/2 the designed minimum metabolic rate) from behind the water bladders into the suit to prevent lockup of the Water Pressure Regulator (I113E). Such a lockup, due to normal leakage from I113E, would cause the Water Tank pressure to rise above the nominal pressure range
120b	Dual Mode Relief Valve - High Mode	Prevents overpressurization of the water tanks in the event that the Water Regulator (I113E) fails open. If the High Mode were to open, flow from this valve would dump into the suit via the T11 port behind the EV crewmember's right shoulder by the neck ring
120b	Dual Mode Relief Valve - Low Mode	Allows fast filling of the water tanks and BTA operation by venting the O2 pressure behind the Water Tank bladders into the suit via the T11 port behind the EV crewmember's right shoulder by the neck ring. Opens when the pressure upstream of the Check Valve (I120c), termed P1, falls more than 1 psi lower than pressure downstream on the Water Tank bladders, termed P2. This happens when the O2 Actuator is taken to or cycled through the OFF position since O2 upstream of the Check Valve backflows into the suit, thereby dropping Pl. This process makes a foghorn sound heard in the T11 port
120c	Check Valve	Prevents backflow of "wet" O2 from behind the H2O bladders from corroding the H2O Pressure Regulator (I113e). Also allows a 1-psi differential to develop to allow opening of the Low Mode Relief Valve (120b)
	Ventilation Loop	Provides O2 circulation, helmet defogging, metabolic CO2 removal, (as well as odor and trace contaminant removal) and ventilation dehumidification
114	Suit Pressure Sensor (range: 0 to 6.0 ± 0.15 psid)	Senses suit pressure with respect to ambient at a point within the PLSS. The CWS (I150) uses the sensor to provide the SUIT P X.X status on the DCM Display (I351). Also used during automated suit Leak Checks and checkout of the SOP (I200). Also provides input for the messages SUIT P EMERG, SOP O2 ON, SUIT P LOW, SUIT P HIGH, and RLF V FAIL. The Suit Pressure Gauge (I311) provides a visual backup to this sensor; it senses suit pressure within the Hard Upper Torso's (HUT's) cavity. The gauge and sensor values should always be compared during pressurized suit operations
121	Check Valve & Vent Flow Sensor (Flow Discrete @ >5.1acfm; Low Flow Discrete @<3.7 acfm)	Acts as one-way check valve to direct O2 flow to Helmet during emergency suit purge operations with the Fan (I123a) off. Also provides insight as to whether the Fan flow is within acceptable limits. The CWS (I150) uses the sensor's discrete value to provide the messages NO VENT FLOW and VENT SW FAIL on the DCM Display (I351)

Table 3-23. PLSS item summary (continued)

Item number	Name	Description
122	IR CO2 Transducer (range: 0.1 to 30 mmHg)	Senses the ventilation flow's CO2 partial pressure level just prior to entering the helmet to provide an indication of CCC (I480) performance. The CWS (I150) uses the sensor to provide the CO2 XX.X MM status on the DCM Display (I351) and the messages MONITOR CO2 and CO2 HIGH. NOTE: The actual CO2 levels in the Helmet can be twice the levels indicated by this transducer; the CWS message limits are set accordingly
123	*Fan/Pump/Water Separator Assembly*	
123a	Fan	Circulates the ventilation loop gases to provide proper helmet washout for control of helmet CO2 levels and ventilation humidity levels. The dynamic pressure created by the Fan flow provides the force needed to open the Check Valve & Vent Flow Sensor (I121) when the I123 Assembly is operating properly and is providing proper flow. Mechanically coupled to the Motor (I123d), which is powered via the Fan Switch (I366) on the DCM (I300)
123b	Water Separator	Through centrifugal forces, separates condensed water from Ventilation Loop, via the Sublimator's (I140) slurper holes and gases/bubbles collected from the Cooling Loop. Water is sent to the Cooling Loop and Feedwater System, and gases are routed to the Ventilation Loop. Mechanically coupled to the Motor (I123d), which is powered via the Fan Switch (I366) on the DCM (I300)
123d	Motor	Rotates the Fan (I123a), Water Separator (I123b), and Water Pump Assembly (I123c) via the Fan Switch (I366) (i.e., all are on at the same time; not controlled separately.) The Fan (I123a) and Water Separator (I123b) are mechanically linked to the Motor, while the Pump (I123c) is magnetically coupled to provide a more positive separation of the Cooling Loop (water) and Ventilation Loop (O2). During EVA, rotates at a nominal 19.5 ± 0.5K RPMs, which is monitored by the CWS (I150) providing the RPM XX.XK status on the DCM Display (I351); there are no associated messages. Since ventilation gas density decreases with airlock depressurization, a speed control circuitry keeps the motor speed below 20K RPMs by pulsing the current to the Motor, preventing overspeed, which would otherwise occur due to the resultant unloading of the Fan (I123a). Operating in speed control results in a decreased amp draw by the Motor. An underspeed circuit shuts down the Motor if the speed falls below 13K RPMs due to excessive loading of I123 Assembly; this shutdown feature is delayed for 5 seconds during Fan startup
126	Filter & Orifice (CO2 Transducer)	Filters the ventilation flow that is bled-off to the IR CO2 Transducer (I122) and limits this bleedoff flow to <1 percent of total ventilation flow
145	SOP Checkout Relief Valve	This item is presently not required to function; this overpressurization protection during checkout of the SOP (I200) is now being provided by the I495 Secondary Oxygen Pack Checkout Fixture (SCOF)

Table 3-23. PLSS item summary (continued)

Item number	Name	Description
146	PPRV	Limits suit pressure in the event of a regulator or relief valve failing open (I113D Suit Pressure Regulator, I113E Water Pressure Regulator, I213 Secondary O2 Pressure Control Module, or I120B Dual Mode Relief Valve). Cracks open at a minimum suit pressure of 4.7 psid. Also limits suit pressure nominally to ~5.1 psid during airlock depressurization. Verified to be reseated at 5 psia during airlock depress; if this valve were to fail open, the flow rate is such that suit pressure would not drop below acceptable limits
147	NPRV	Limits suit negative pressure in the event of an emergency airlock repressurization with low O2 tank pressures, preventing suit from collapsing in on the crewmember. Cracks open and reseats closed at 0.2 psid
105b	Combination (Helmet) Purge Valve	Provides a controlled opening from the suit to the environment through helmet. Used in an off-nominal open loop purge, such as for high C02 or vent flow contamination. Flows ~2.5 lb/hr of O2 at vacuum. NOTE: Always lock in the open or closed position. CAUTION: Never have both purge valves open; Primary + SOP O2 flow could not keep up with a flow rate this high, and the suit pressure would stabilize at ~2.5 psi, which is below the metabolic pressure requirements
314	Purge Valve (DCM)	Provides a controlled opening from the suit to the environment. Used to purge nitrogen from the suit prior to EVA. Flows ~5.0 lb/hr of O2 at vacuum. Detents lock valve in both the open and closed positions. NOTE: Red should not be visible when valve is fully closed; closure should be completed by pressing down on top of the valve with the thumb. CAUTION: Never have both purge valves open; Primary + SOP flow could not keep up with a flow rate this high, and the suit pressure would stabilize at ~2.5 psi, which is below the metabolic pressure requirements
311	Suit Pressure Gauge (range: 0 to 5.5 psid) (accuracy: ± 0.1 from 3-5.0 psid ± 0.2 over remainder)	Provides a constant visual indication of the suit pressure with respect to ambient; senses suit pressure within the Hard Upper Torso's (HUT's) cavity. The coloring on the gauge face DOES NOT indicate nominal operating ranges for the current EMU design pressures. The Suit Pressure Sensor (I114) provides a backup to this gauge; it senses suit pressure within the PLSS's ventilation lines. The gauge and sensor values should always be compared during pressurized suit operations
480	Contaminate Control Cartridge (CCC)	Controls the levels of CO2, trace gases, and odors within the EMU Ventilation Loop. Monitoring of the cartridge's CO2 scrubbing performance is provided by the IR CO2 Transducer (I122). Two types of cartridges with different reactants may be used in an EMU: Lithium Hydroxide (LiOH) and Metal Oxide (Metox). Metox is used on the ISS since it may be regenerated. The cartridges themselves also differ, with the Metox cartridge being thicker and containing an indicator to show whether the cartridge has been regenerated or spent

Figure 3-23. PLSS item summary (continued)

Item number	Name	Description
	Cooling Loop	Circulates water for heat transfer and rejection to provide cooling to the crewmember [via the Liquid Cooling and Ventilation Garment (LCVG)], the Ventilation Loop, and the EMU electronics
123c	Water Pump Assembly	Circulates the cooling loop water from the Liquid Cooling and Ventilation Garment (LCVG) and DCM electronics to the vehicle heat exchanger and/or EMU Sublimator (I140), providing heat rejection. Magnetically coupled to the Motor (I123d), which is powered via the Fan Switch (I366). Motion of bubbles or presence of cooling in the LCVG tubing indicates flow. CAUTION: Minimize Pump operation with the O2 Actuator in off (i.e., when the Cooling Loop is not pressurized)
125	Pitot Actuated Valve (Pump Priming Valve)	Isolates the Ventilation Loop gases from Cooling Loop water, when closed, and allows degassing of the Cooling Loop, when opened. Automatically opens (Pitot-actuated) once condensed ventilation water reaches the Water Separator (I123b) and causes a pressure buildup behind the Condensate Water Relief Valve (I134.) The Pump-Priming feature manually opens the valve when its button, located on the back of the PLSS, is pressed. The resultant water flow through the valve and pressure drop in the Cooling Loop cause makeup water from the Feedwater System to rush through the Water Pump (I123c.) NOTE: Flooding of the Ventilation Loop could occur if this valve were to fail open; this is protected against by the Coolant Isolation Valve (I171)
127	Pump Inlet Filter	Filters makeup water, supplied from the Feedwater system or Condensate Water Relief Valve (I134), prior to its entering the pump; protects the Pump (I123C) from possible damage by contaminants
128	Check Valve and Housing (Pump)	Prevents reverse Cooling Loop flow and ensures the pump will start with gas in the Cooling Loop by directing makeup water flow directly through the Pump (I123C), which should cause priming
139	Sublimator Outlet Temperature Sensor	Senses the temperature of the cooling water leaving the sublimator and helps determine the health of the sublimator. The CWS (I150) uses the sensor to provide the H2O TEMP XX status on the DCM Display (I351); there are no associated messages
140	Sublimator	Cools the Ventilation and Cooling Loops by sublimating feedwater to vacuum (i.e., heat exchanger.) Feedwater flow to the Sublimator is allowed only when the WATER switch is on. CAUTION: This switch should be turned on only when at vacuum. The Sublimator also dehumidifies the Ventilation Loop by causing H2O to condense out; a hydrophilic coating in the Sublimator wicks this condensate by capillary action to Sublimator’s slurper, where a slight pressure difference causes this H20 and ~1 to 10 percent of vent flow to be sent to Water Separator (I123b). When connected to the vehicle via the SCU Interface (I330), the Cooling Loop and Sublimator are cooled by the vehicle’s heat exchanger. Due to the proximity of the Ventilation Loop passages to the Cooling Loop passages within the sublimator, vent flow cooling and dehumidification also occur

Table 3-23. PLSS item summary (continued)

Item number	Name	Description
141	Gas Trap	Traps bubbles in the Cooling Loop and directs them, along with some bleedoff water, to the Water Separator (I123b) via the Pump-Priming Valve (I125). Also removes particulate contamination from the water flow to the pump
321	Temperature Control Valve	Modulates the Cooling Loop flow to the Sublimator (I140) and LCVG to allow the crewmember to control the amount of cooling to the suit. Turning this proportioning valve's handle adjusts the mixing of warm water from the pump and cool water from the sublimator sent to the LCVG. As the valve is rotated from the maximum cold "C" position toward warmer positions, around the "2" position flow through the sublimator to the LCVG is stopped, resulting in only warm water being recirculated through the LCVG. Around the maximum hot "H" position, all flow to the LCVG is stopped; this is termed LCVG bypass because a small amount of flow bypasses the LCVG and is routed to the Pump (I123D) and DCM (I300) for component cooling
	Feedwater System	Provides expendable water to the Sublimator (I140) and Cooling Loop. Also provides pressurization of the Cooling Loop
131 162	Primary Water Tank #1 Primary Water Tank #2	Store expendable water to be supplied to the Sublimator (I140) for heat rejection capability during an EVA and provide makeup H2O for Cooling Loop to replace volume lost to bubbles or leakage in the loop. Designed to hold a total of ~8 lb of H2O to provide cooling capability for a 7-hour EVA; actual consumption during previous missions was significantly less than this (~4 lb in 7 hr)
132a	O2 Feedwater Supply Pressure Sensor (range: 0 to 40 ± 1psia)	Senses the O2 pressure behind the water tank bladders that provides pressurization of the Feedwater and Cooling Loop, allowing monitoring of the Water Pressure Regulator's (I113e) operation. The CWS (I150) uses the sensor to provide the H2O GP XX.X status on the DCM Display (I351) and the message H2O GP LOW, as well as allowing the RESRV H2O ON message in combination with the H2O Feedwater Supply Pressure Sensor (I132b)
132b	H2O Feedwater Supply Pressure Sensor (range: 0 to 40 ± 1psia)	Senses the water pressure within the Primary Water Tanks. The CWS (I150) uses the sensor to provide the H2O WP XX.X status on the DCM Display (I351), as well as allowing the RESRV H2O ON message in combination with the O2 Feedwater Supply Pressure Sensor (I132a). When this sensor's reading falls 2.1 psi below that of I132a (i.e., when the water pressure falls below that of its pressurization source, plus sensor error), the RESRV H2O ON message is issued and a 30-minute countdown timer is started
134	Condensate Water Relief Valve	Provides backpressure to the Water Separator (I123b) to ensure efficient gas separation and prevents water from flooding the Ventilation Loop when the Fan/Separator/Pump (I123) is off. NOTE: If this valve fails open, flooding is protected against by the Coolant Relief Valve (I172)

Table 3-23. PLSS item summary

Item number	Name	Description
135	Feedwater Relief Valve	Prevents overpressurization of the Cooling and Feedwater System by relieving small amounts of water to ambient, just below the access area to the Pump Priming Valve (I125). Cracks and reseats between 18 to 20 psid with respect to ambient
136	Feedwater Pressure Regulator	Regulates the pressure of the feedwater down to ~3 psid to allow proper sublimator operation, preventing sublimator breakthrough that would occur at the Feedwater Tanks' pressure levels. Proper operation of this regulator is monitored by the Feedwater Pressure Sensor (I138)
137	Feedwater Shutoff Valve	Isolates the feedwater from the sublimator when not at vacuum. This solenoid valve is opened and closed when the WATER switch is taken on and off, respectively. The valve latches, such that if power is lost, the valve remains in the last commanded position. CAUTION: Should always remain closed (i.e., WATER sw - OFF) when not at vacuum
138	Feedwater Pressure Sensor (range: 0 to 16 +/-0.4 psia)	Senses sublimator water pressure (or ambient pressure when the sublimator is not active). Provides an indication of the health of the Feedwater Pressure Regulator (I136) and Sublimator (I140) or measures the absolute pressure of the airlock. The CWS (I150) uses the sensor to provide the SUBLM P or AIRLK P status on the DCM Display (I351), and the message SUBLM P XX.X/SET H2O OFF. Loss of this sensor will greatly affect CWS operation
142	Water Relief Valve (Reserve)	Isolates the Reserve Water Tank (I148) until the Primary Water Tanks are depleted. Prevents the reserve feedwater from being used until the primary tanks' water pressure drops by at least 4 psid, at which point this valve cracks open and reserve water begins to be consumed; reseats (closes) at 3 psid. With this design, the RESRV H2O ON message will have enunciated prior to this valve opening, resulting in a conservative time left estimate
143	Water Check Valve (Reserve fill)	Isolates the reserve water tank from the primary tank during feedwater use. Permits Reserve Water Tank (I148) recharging in parallel with the Primary Water Tanks (I131/I162)
148	Reserve Water Tank	Contains ~1 lb of expandable water reserves for 1/2 hour of cooling. Tank is isolated by the Water Relief Valve (I142) and the Water Check Valve (I143) until the Primary Water Tanks' pressure falls 4 psid
171	Coolant Isolation Valve	Protects against a failed open Pump Priming Valve (I125), which would flood the Ventilation Loop when the Water Separator (I123b) is not running and the Feedwater System is pressurized (i.e., O2 Actuator taken out of the OFF position). This solenoid valve opens and closes when the Fan Switch (I366) is taken on and off, respectively. The valve latches, such that if power is lost, the valve remains in the last commanded position
172	Coolant Relief Valve	Allows ventilation condensate to relieve to the Water Tanks (I131, I162, I148) and protects the Ventilation Loop from flooding if the Condensate Relief Valve (I134) were to fail open

Table 3-23. PLSS item summary (continued)

Item number	Name	Description
200	**Secondary Oxygen Pack (SOP)**	Provides emergency life support for 30 minutes in the event of a primary Life Support System (PLSS) failure. Provides O2 for pressure control, metabolic consumption, and leakage makeup as well as cooling and contaminant (CO2 and H2O vapor) control when used in conjunction with a purge valve
210	Secondary O2 Bottles	The two tanks together are designed to provide enough emergency O2 for 30 minutes (~2.5 lb @ 5800 psi). This 30-minute emergency design is based on a leakage rate equivalent to the flow from the DCM Purge Valve (I314) as might be needed during an emergency purge operation. Cannot be refilled on orbit
213	*Secondary O2 Pressure Control Module*	
213b	O2 Pressure Regulator (First Stage)	Controls the Second-Stage inlet pressure by regulating the SOP Tank pressure down to ~200 psi to allow optimum Second Stage Regulator (I213d) performance. If the First Stage Regulator were to fail open, the Second Stage Regulator is designed to still regulate in its nominal range. If this regulator fails open, the SOP in not usable for EVA
213d	Second Stage Regulator, Flow Restrictor, Shutoff Valve	The shutoff valve feature is closed in all O2 Actuator positions except EVA. When in the EVA position, this regulator will open and flow SOP O2 automatically if the suit pressure drops below ~3.9 psid (e.g., Major suit leak) and would regulate between 3.33 to 3.9 psid, depending on flow demand. If this regulator failed open, the flow would be restricted to ~7.5 lb/hr, a rate which the PPRV (I146) can allow flow to relieve to vacuum, preventing suit overpressurization
213e	SOP Pressure Gauge (range: 0 to 8000 ± 400 psi)	Provides a visual indication of the SOP Tank pressure during Intravehicular Activities. Constant monitoring of SOP Tank pressure during EVA is provided by the SOP Tank Pressure Transducer (I215). This gauge is not visible after donning the EMU
213f	Fill Valve Assembly	Provides connection for GSE to refill the tanks and prevents backflow/leakage when the Fill Fitting is removed
213g	SOP Interstage Pressure Gauge (range: 0 to 8000 ± 400 psi)	Measures the First Stage Regulator's (I213b) outlet pressure. Gauge allows a check of the First Stage Regulator's performance during SOP Checkout. This gauge is not visible after donning the EMU
215	Pressure Transducer (SOP Tank) (range: 0 to 7400 ± 259 psia)	Senses the SOP Tank pressure to determine the health of the emergency system and the time remaining during usage; this is the only insight the CWS (I150) has into the SOP (I200). The CWS uses the sensor to provide the SOP P status on the DCM Display (I351), and the message SOP P LOW, SOP O2 ON/ TIME LF X:XX. NOTE: Sensor can be affected by Radio Frequency (RF) interference, resulting in fluctuations in the readings

Table 3-23. PLSS item summary (continued)

Item number	Name	Description
150	**Caution & Warning System (CWS)**	Monitors analog and discrete signals from DCM, PLSS, and SOP to determine the overall status and health of the EMU. Displays status and messages on DCM (I300) and generates tones via the comm system to provide the crewmember current information on EMU operation and consumables use. Also transmits sensor and calculated data to the RTDS (I174) for transmission to ground support personnel
174	**Real-Time Data System**	Provides interface between the CWS (I150) and EMU Communications system, allowing transmittal of the EMU sensor data and crewmember biomedical data to the ground via the vehicle
300	**Display & Control Module (DCM)**	Provides power distribution and housing for EMU operation controls. Also, provides fluid and electrical interfacing between the EMU and vehicle. It consists of two separate components, the Electronics Assembly and Oxygen/Water Manifold Assembly
115	Slide Actuator (O2 Actuator)	Permits manual selection of one of four EMU pressure control configurations: (1) OFF - SOP Shutoff Valve (I213d)and O2 Shutoff Valve (I113c) both closed. (2) IV - SOP Shutoff Valve closed, O2 Shutoff Valve open, and Suit Pressure Regulator (I113d) operating at 0.9 psid. (3) PRESS - SOP Shutoff Valve closed, O2 Shutoff Valve open, and Suit Pressure Regulator operating at 4.3 psid. (4) SOP Shutoff Valve open, O2 Shutoff Valve open and Suit Pressure Regulator (I113d) operating at 4.3 psid. Electrical position switches provide indication to the CWS (I150) of the O2 Actuator's position. The CWS (I150) uses these electrical switches, along with the EVA Position Switch (I116), to provide the O2 ACT - XXX status on the DCM Display (I351)
311	Suit Pressure Gauge	Description above; see Ventilation Loop
314	Purge Valve (DCM)	Description above; see Ventilation Loop
321	Temperature Control Valve	Description above; see Cooling Loop
330	Common Multiple Connector (SCU Interface)	Interfaces with the SCU (I400) to allow charging of the Primary O2, Feedwater, and Electrical systems as well as providing Hardline communications and airlock operation capability. The fluid system circuits are self-sealing when the SCU is disconnected. This connector contains a warm water flow path (bypass valve) to the Sublimator (I140) when SCU is disconnected; when the SCU is connected, this flow path is closed, forcing the flow through the vehicle's heat exchanger. The cool H2O returns to the Sublimator in the EMU's Cooling Loops circuit, providing suit cooling during suited operations in the airlock

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Table 3-23. PLSS item summary (continued)

Item number	Name	Description
350	Electronic Assembly (DCM)	Provides current limiting for the EMU radio, Feedwater Shutoff Valve (I137), and Coolant Isolation Valve (I171). Also contains the battery current and voltage sense circuitry. The CWS uses this circuitry to provide the BAT VDC XX.X and BAT AMP X.X status on this assembly's DCM Display (I351), and the messages BATT VDC LOW, BATT AMPS HI, and % PWR LF XX/ TIME LF X:XX
351	LCD Module (DCM Display)	Contains the Built-In Test Equipment (BITE) indicator and Alphanumeric display. The BITE indicator provides visual indication of a CWS (I150) failure. The alphanumeric display provides EMU instrumentation data and system fault messages. The display consists of 12 characters. Backlighting provides visibility in dark environments; the backlighting intensity is controlled via the Display Intensity Control (I361)
360	Volume Control	Permits independent control of voice signal levels received by the redundant EMU radios. The upper controls volume during Hardline (HL) and Primary (PRI) communications; the lower controls volume during use of the Alternate (ALT) EMU radio
361	Display Intensity Control	Controls the DCM Display (I351) backlighting from 1/2 to full brightness to provide display visibility in dark environments
362	Comm Mode Selector Switch	Provides the capability to select one of three communications modes: HL enables hardline communication, PRI powers the primary transceiver, and ALT powers the alternate transceiver. OFF completely powers down EMU communications
364	Power Mode Selector Switch	Provides the crewmember a manual means of switching the EMU between vehicle power and battery power. The CWS (I150) receives an electrical discrete indication of the switch's position
365	Comm Frequency Switch (Push-to-Talk Switch)	Determines the operating frequency of the EMU radio. In the LOW position, the powered radio operates at 414.2 MHz. LOW will nominally be used for EVA. HIGH selects 417.1 MHz as the operating frequency. NOTE: ALL users in the communication network must be operating on the same frequency to avoid disruption of comm. While in RF, Voice-Operated Transmit (VOX) operation may be momentarily muted by going to the spring-loaded PTT/MUTE position of this switch. While using HL comm, the PTT/MUTE position allows microphone inputs to pass to the vehicle as a Push-To-Talk (PTT) signal
366	Fan Switch	Provides the crewmember a manual means of controlling power flow to the Motor (I123c) and isolates the Cooling Loop from the Feedwater System when this switch is off (i.e., water separator is not operating.) The Coolant Isolation (I177) solenoid valve opens and closes when this switch is taken on and off, respectively. The CWS (I150) receives an electrical discrete indication of the switch's position
367	Feedwater Valve Switch	Isolates the feedwater from the sublimator when not at vacuum. The Feedwater Shutoff (I137) solenoid valve is opened and closed when this switch is taken on and off, respectively. The CWS (I150) receives an electrical discrete indication of the switch's position. CAUTION: Should always remain off when the EMU is not at vacuum

Table 3-23. PLSS item summary (continued)

Item number	Name	Description
368	CWS Switch (Display Switch)	Provides the crewmember access to the both the EMU Status Parameters List and the EMU Fault Message Stack via the DCM Display (I351). The CWS (I150) receives an electrical discrete indication of the switch's position. Depressing to the STAT position will display the status list one parameter at a time. If a parameter is displayed for more than 20 seconds, the display returns to the default message. Depressing to the STAT position again returns the display to the last parameter displayed by the crewmember. Depressing the switch to the PROC position will display the first parameter in the status list. Depressing to the PROC position from here will display the Fault Message Stack. Each message will be displayed for 8 seconds in succession per the predefined priority order; further switch cycling is not required to proceed to next message. This switch position also is used to acknowledge a Fault Message and extinguish its warning tone (warble), and to initiate an automated EMU leak check when "LEAK CHECK?" is being displayed in the Status List
400	**Service and Cooling Umbilical (SCU)**	Provides an electrical and fluid interface between the EMU and the vehicle, providing vehicle Oxygen, cooling, electrical power, and Hardline communications during airlock operations. Also provides Primary Oxygen, Feedwater, and battery recharge capability to the EMU. The length and components of the SCU are dependent on the vehicle

Section 4
Ancillary Equipment

The EMU ancillary equipment consists of the hardware that is necessary to support the EMU during all phases of EVA (prep/during/post); it includes the following components:

a. EMU helmet lights

b. EMU scissors

c. EMU wrist mirror

d. EVA cuff checklist

e. Mini-workstation

f. Thermal mittens

g. Waist tethers

h. Wrist tethers

i. LTA donning handles

j. BSC contingency tool

k. Bends treatment adapter

l. SOP checkout fixture

m. DCM plug

n. Prep kit

o. Maintenance kit

p. EMU equipment bag

q. EVA bag

r. SAFER

4.1 EMU Helmet Lights

The EMU lights attach to the helmet/EVVA and provide two functionally independent sets of lights for portable lighting during EVA. Two versions are now used, called the First and Third Generations. The two generations are discussed in separate sections. The second generation of helmet lights is not currently used.

4.1.1 First Generation EMU Helmet Lights

The first generation helmet lights are the older version and are used only on flights without a scheduled EVA. These lights include the following components:

a. Left and right lamp housings

b. Crossmember

c. Battery modules

d. Power control switches

e. Thermostatic cutoff switches

f. Attachment latches

g. TMG

The assembly consists of two independent lamp modules connected by a crossmember (Figure 4-1). Each side has a lithium battery module (Figure 4-2), two identical lamps, a power control switch, and a thermostatic cutoff switch.

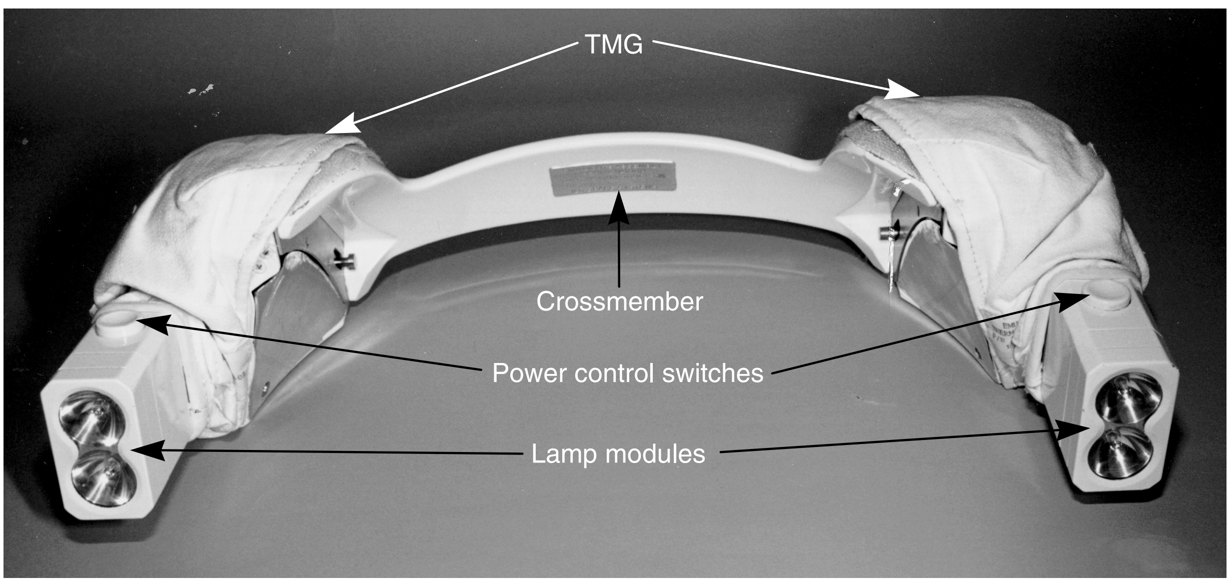

Figure 4-1. First generation helmet light assembly

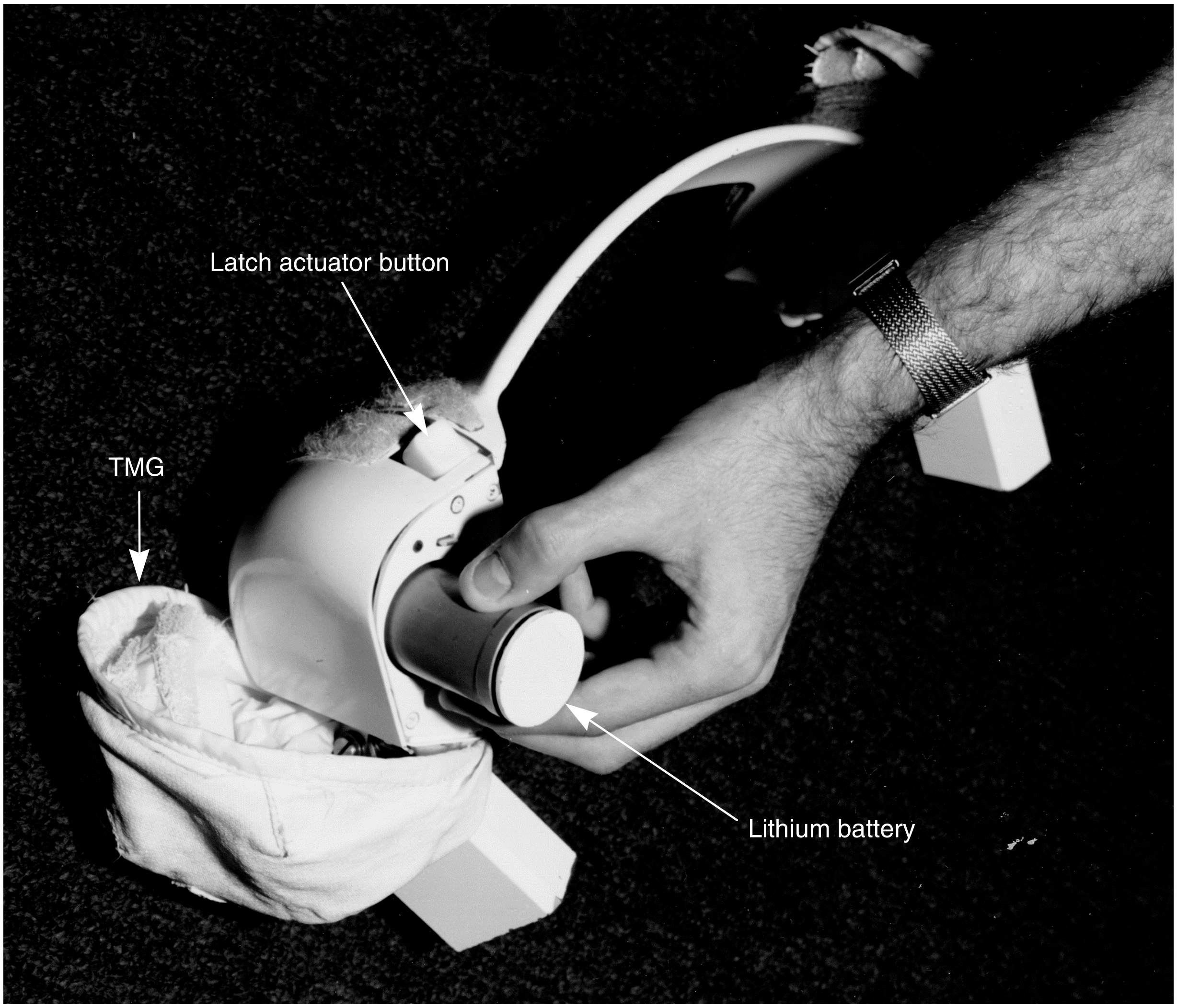

Figure 4-2. Lithium battery modules

The helmet lights attach to the back of the EVVA with four retractable latches (Figure 4-3). Two latch actuator buttons are on the exterior of each battery module cover. TMG is attached with Velcro to each of the battery module covers and can be moved to access the latch actuator buttons.

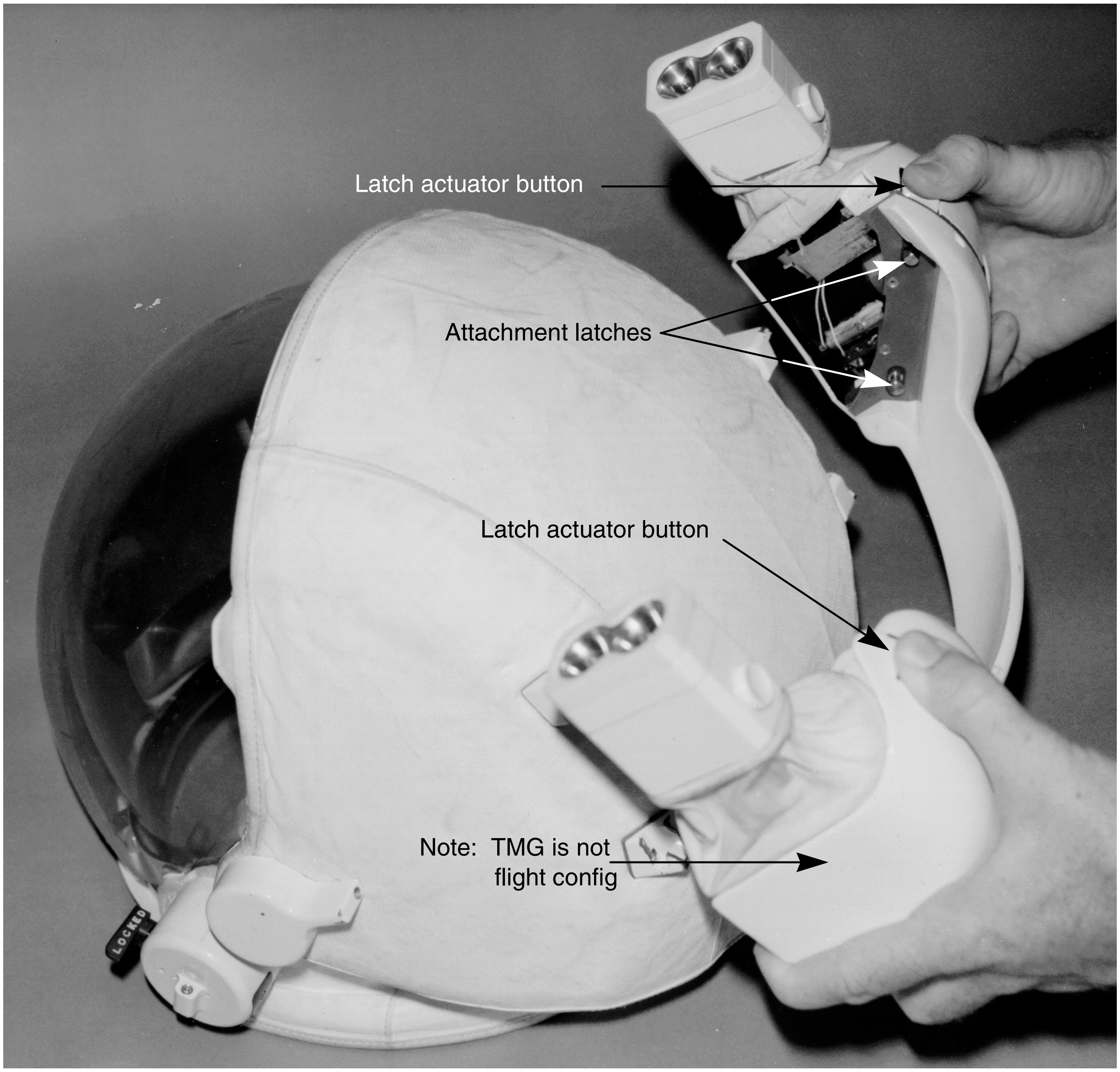

Figure 4-3. First generation helmet light attachment

Each lamp module gimbals 5° toward the helmet, 80° away from the helmet, 30° up, and 30° down.

The power control switches, located at the top of each lamp module, provide one-hand operation of the lamps. The first switch press turns on the upper lamp only, the second press turns off the upper lamp and turns on the lower lamp, and the third press turns the lower lamp off. Both lamps on a side cannot be activated at the same time, because the thermostatic cutoff switch on each side turns off the lamps if the module reaches a temperature of 160° F.

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Each battery module can supply power to illuminate one lamp for 6 hours with less than 10 percent degradation of light intensity. Battery modules can be replaced in flight after each EVA.

When the batteries sit after being partially discharged, a chloride film forms within them, which temporarily reduces available voltage and current. Crewmembers need to check the lights a few minutes after activation because this passivation layer dissolves, allowing full power to the lamps. Once the passivation layer dissolves, batteries begin to degrade, so the lights must be turned off immediately.

4.1.2 Third Generation EMU Helmet Lights

The third generation helmet lights (Figure 4-4) are used on flights with a scheduled EVA. Advantages of these lights compared to the first generation lights include:

a. Rechargeable batteries

b. Longer operation on a single battery charge

c. Much brighter light

d. Ability to change batteries during EVA

e. Spotlight and floodlight patterns

f. Improved gimballing of the lights

The third generation lights include the following components:

a. Left and right lamp housings

b. Crossmember

c. Battery packs

d. Power control switches

e. Polyswitch current limiter

f. Attachment latches

g. TMG

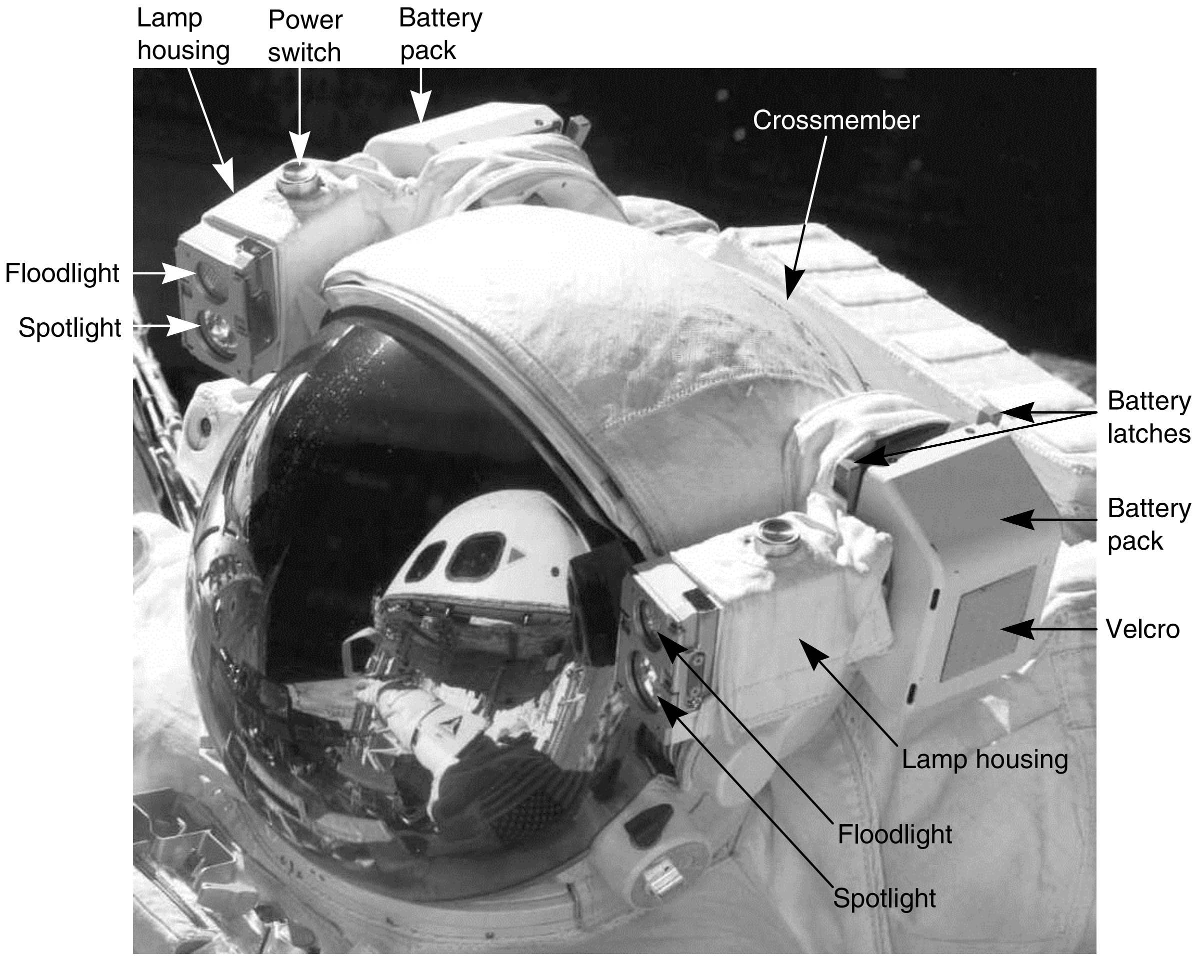

Figure 4-4. Third generation helmet lights

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Each light housing contains a floodlight and a spotlight. The lights are IV replaceable 6-watt halogen bulbs. A rechargeable Nickel Metal Hydride (NiMH) battery pack (Figures 4-5 and 4-6) is attached to each light housing and provides power for up to 9.5 hours of continuous operation. As in the first generation lights, the left and right sides are connected by an aluminum crossmember and attach to the helmet with latches.

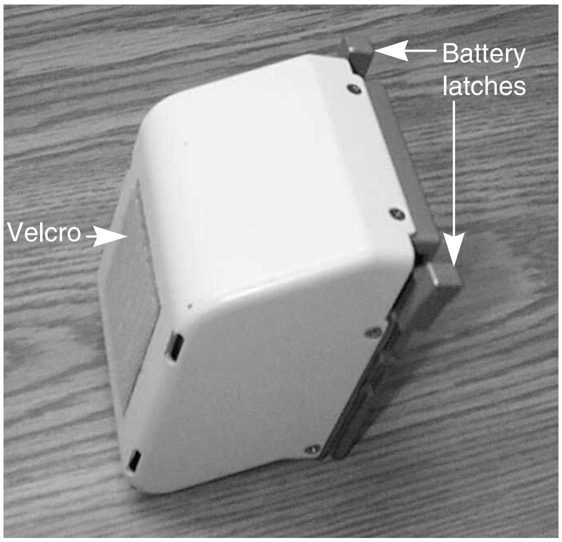

Figure 4-5. NiMH battery pack

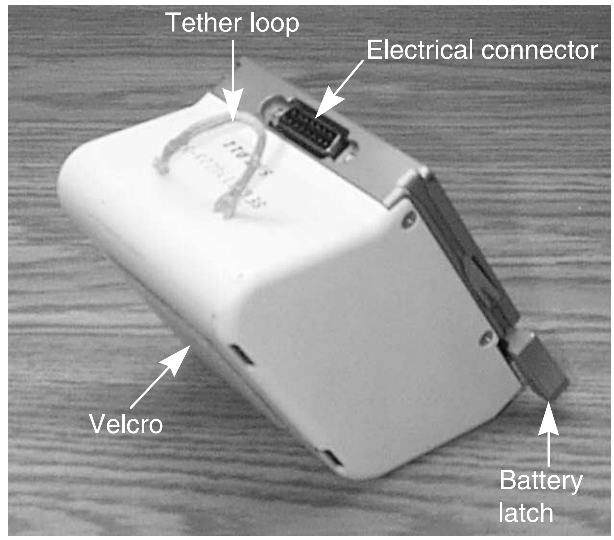

Figure 4-6. NiMH battery pack

Light activation also is similar to that for the first generation lights: pressing the power control switch on the light housing once turns on the floodlight, pressing the switch a second time turns off the floodlight and turns on the spotlight, and pressing the switch a third time turns off the spotlight. Both lights on a side cannot be activated at the same time to prevent overheating of the unit.

Each lamp housing gimbals 30° up, 30° down, 13° toward the helmet, and 45° away from the helmet.

Each rechargeable NiMH battery pack contains 15 NiMH cells and a polyswitch current limiter that provides overtemperature and overcurrent protection. The packs have a small tether attached to them and may be changed out during EVA. Velcro on the pack allows for temporary storage of the helmet lights. The batteries have more capacity than the first generation batteries, but also self-discharge faster (about 1 percent per day), so they must be topped off within 5 days of an EVA. This is done with the helmet light battery charger.

The helmet light battery charger (Figure 4-7) has four charging stations in which it can simultaneously and independently charge four battery packs. It receives power from the orbiter 28 V power supply and has 16 LEDs (four per charging station) that indicate the stage of each battery pack charge. To charge a battery pack, a crewmember simply slides it into the charger and periodically checks the LEDs for that station.

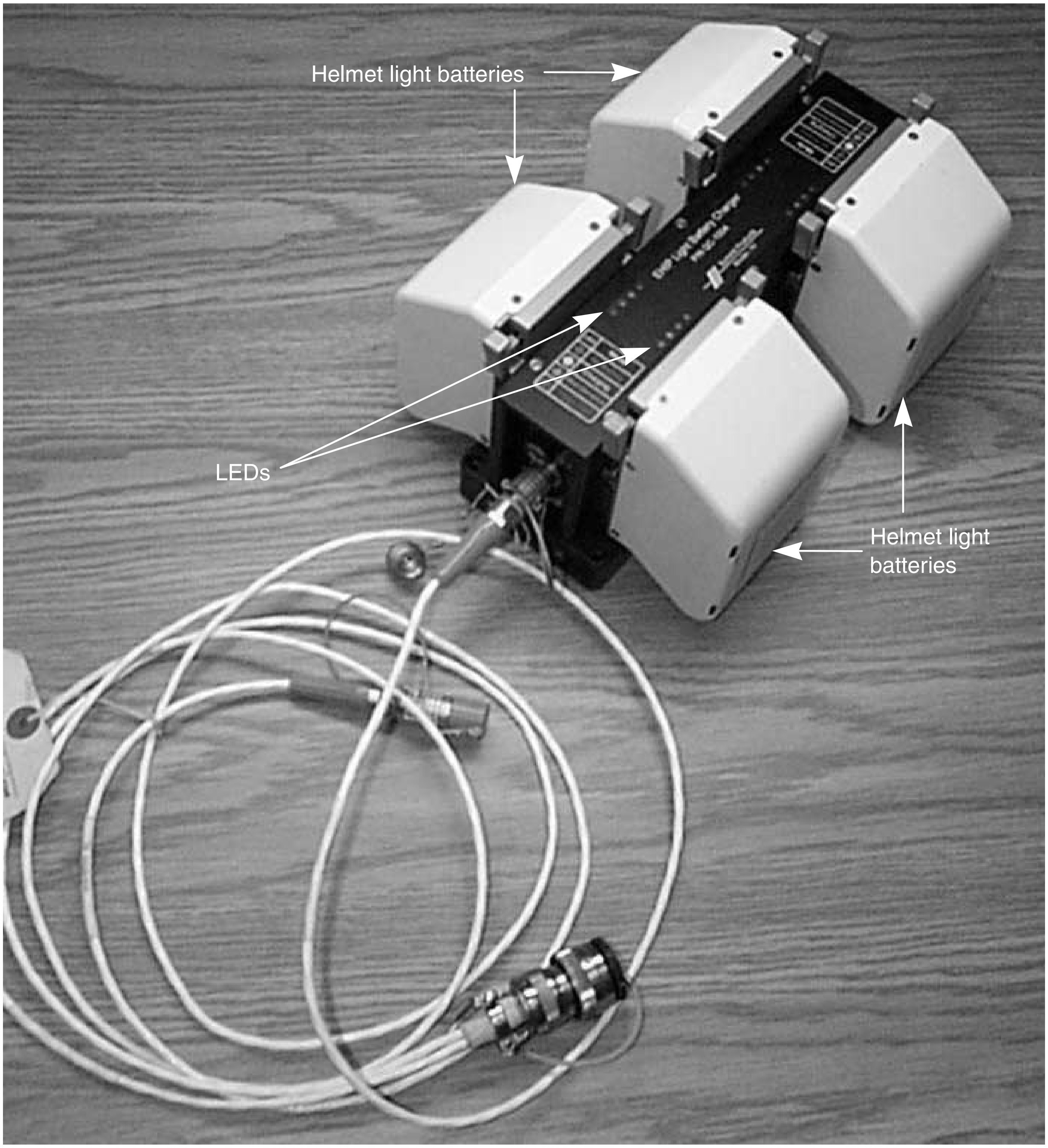

Figure 4-7. Helmet light battery charger with four battery packs

The four LEDs on each station and their associated indications are as follows: STANDBY/RE-INSTALL (blue), CHARGING (yellow), MAINTENANCE (green), and TEMP FAULT (red) (Figure 4-8). At least one LED for each charging station is illuminated at all times if power is applied to the charger.

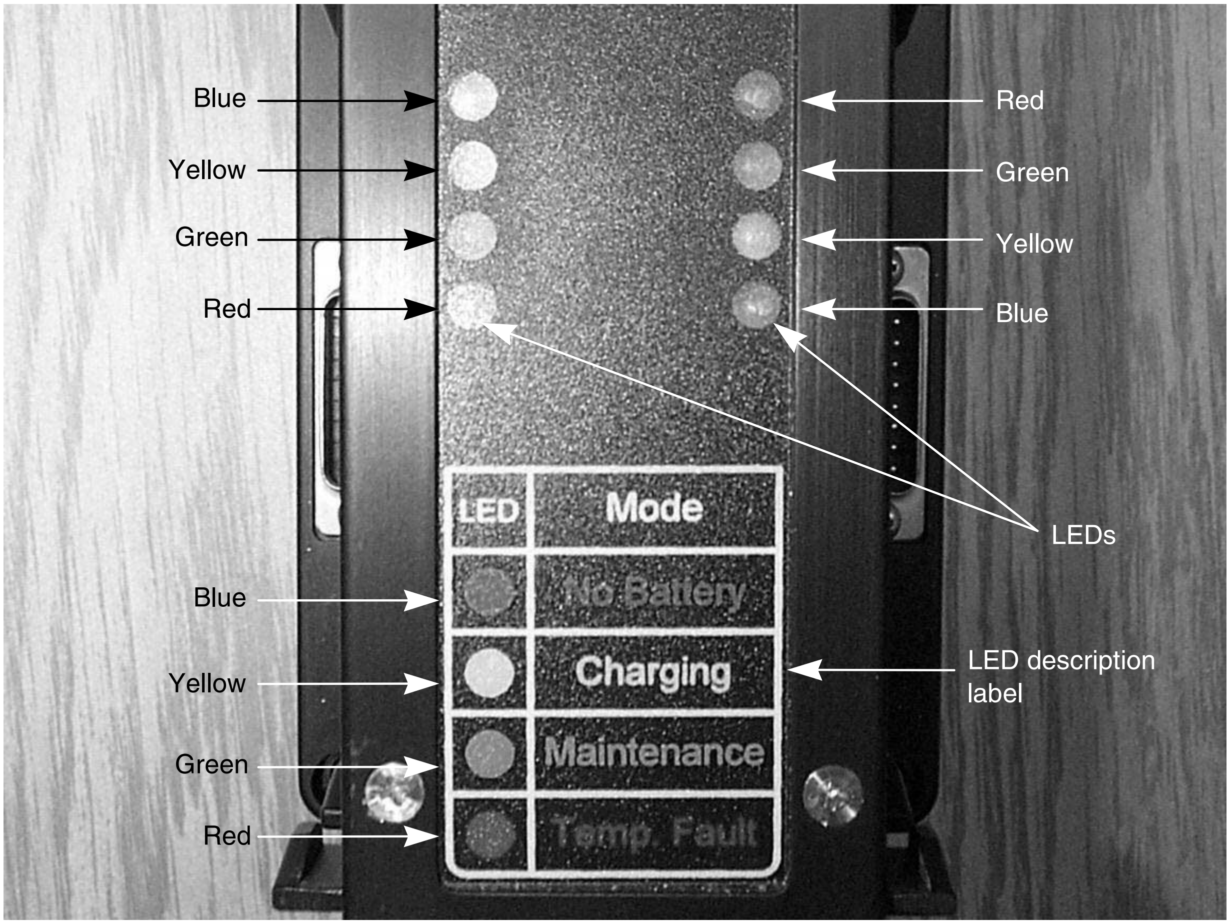

Figure 4-8. Helmet light battery charger LEDs and LED label

The STANDBY/RE-INSTALL LED (blue) indicates that the station is receiving power but there is no battery pack connected to the station. If a battery pack has been installed and the STANDBY/RE-INSTALL LED is illuminated, the crewmember should verify that the battery pack is fully seated. When a battery pack is removed from the station, this LED illuminates.

The CHARGING LED (yellow) illuminates immediately after installing a battery pack in the charging station. This is true even for a freshly charged battery. If a fully charged battery is placed in the charger, it may take 5-15 minutes to receive the green LED indicating that the charge is complete. This is because it takes time to trigger the termination algorithms that indicate a full charge. The battery reaches >95 percent capacity every time it is fully charged. The yellow LED remains on until charging is complete. It takes approximately 5 hours to charge a depleted battery, but the battery pack can be left in the charging station indefinitely.

The MAINTENANCE LED (green) illuminates when the battery pack is fully charged. This LED indicates that the topping charge (or maintenance charge) stage is active. The charger will trickle charge the battery, keeping it at peak charge.

The TEMP FAULT LED (red) lights if the internal battery skin reaches a temperature of ≥131° F. This equates to a battery housing touch temperature of approximately 113° F. The crewmember must remove the battery pack and let it cool to room temperature. This also resets the station (as will be shown by the STANDBY/RE-INSTALL LED). When the battery pack reaches room temperature, it may be reinstalled into the station for charging.

Both the MAINTENANCE LED (green) and the TEMP FAULT LED (red) illuminate if the battery is too cold (≤50° F). The charger warms the battery pack at a reduced charging rate until a normal charge can be applied (this is the same level of charging that occurs during the maintenance charge). When the battery reaches 50° F, the CHARGING LED (yellow) illuminates and thus indicates normal charge has been initiated (the other LEDs will extinguish).

The battery packs generate heat while charging. The charger fan removes this heat through vents in the charger. If the fan is inoperative, the charger should not be used. When the fan is operating properly, the crewmember can hear it and feel flow out the vent on the opposite end of the charger from the power connector.

Although battery packs may be left in the charger indefinitely and trickle charged, they must be stowed in lockers for launch and entry.

4.2 EMU Scissors

The EMU scissors (Figure 4-9) are a contingency cutting tool and may be used to free a crewmember in the event of extreme entanglement in the safety tether or other lines. The scissors are made of steel and are capable of cutting anything from fabric bags and straps to lightweight steel cable and Kevlar cord. A hand stop helps with use while EVA. A small, second blade on the back of the hinge point cuts cable or cord as large as 0.125 inches in diameter.

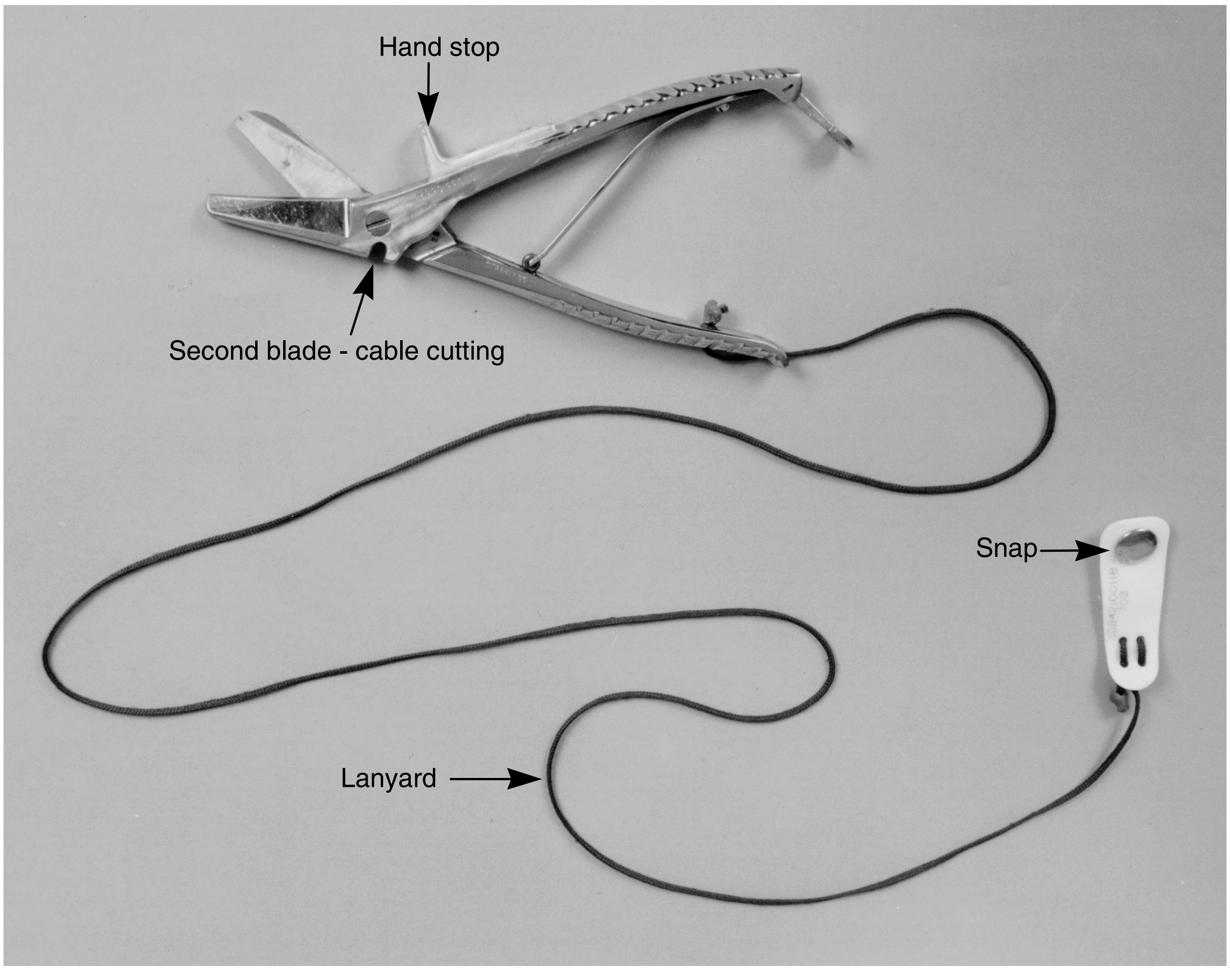

Figure 4-9. EMU scissors

The scissors are stowed in a pocket on the front of the right thigh of the LTA (Figure 4-10) and are restrained by a 4.5-foot lanyard that is snapped inside the LTA pocket. Once the scissors are removed from their pocket, they are difficult to restow during EVA because of reach and visibility limitations. A second crewmember may be able to restow them, or they can be placed in the PSA or in the EVA bag.

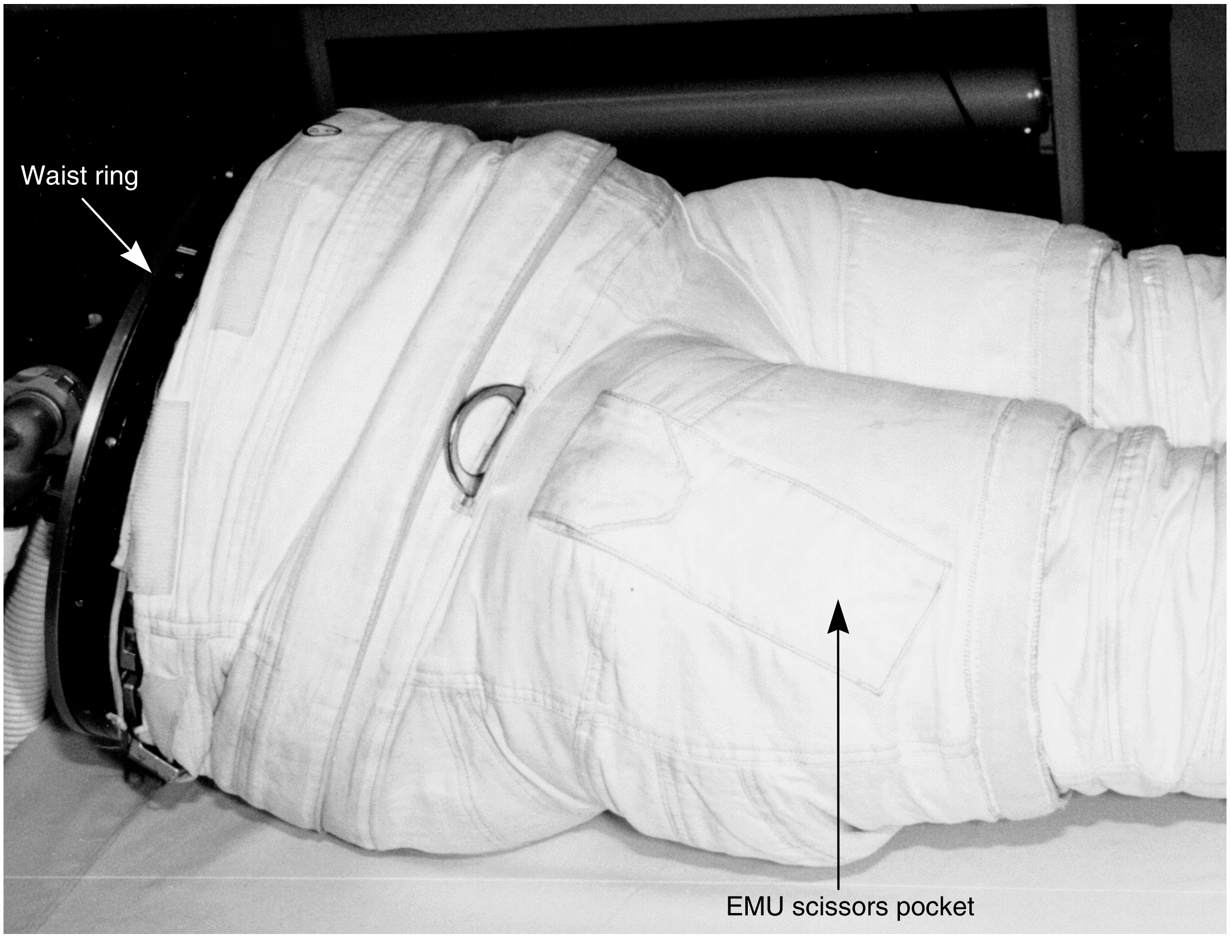

Figure 4-10. EMU scissors stowage pocket

4.3 EMU Wrist Mirror

The EMU wrist mirror fits around the wrist of the EV glove to allow the EVA crewmember to view the DCM labels, which are printed backwards. The mirror can be worn on either wrist.

The mirror is constructed of highly polished chrome-plated steel. The wristband is a stainless steel Twistoflex watchband encased in Teflon fabric. The mirror is attached to the band by straps that loop through slots in the mirror (Figure 4-11).

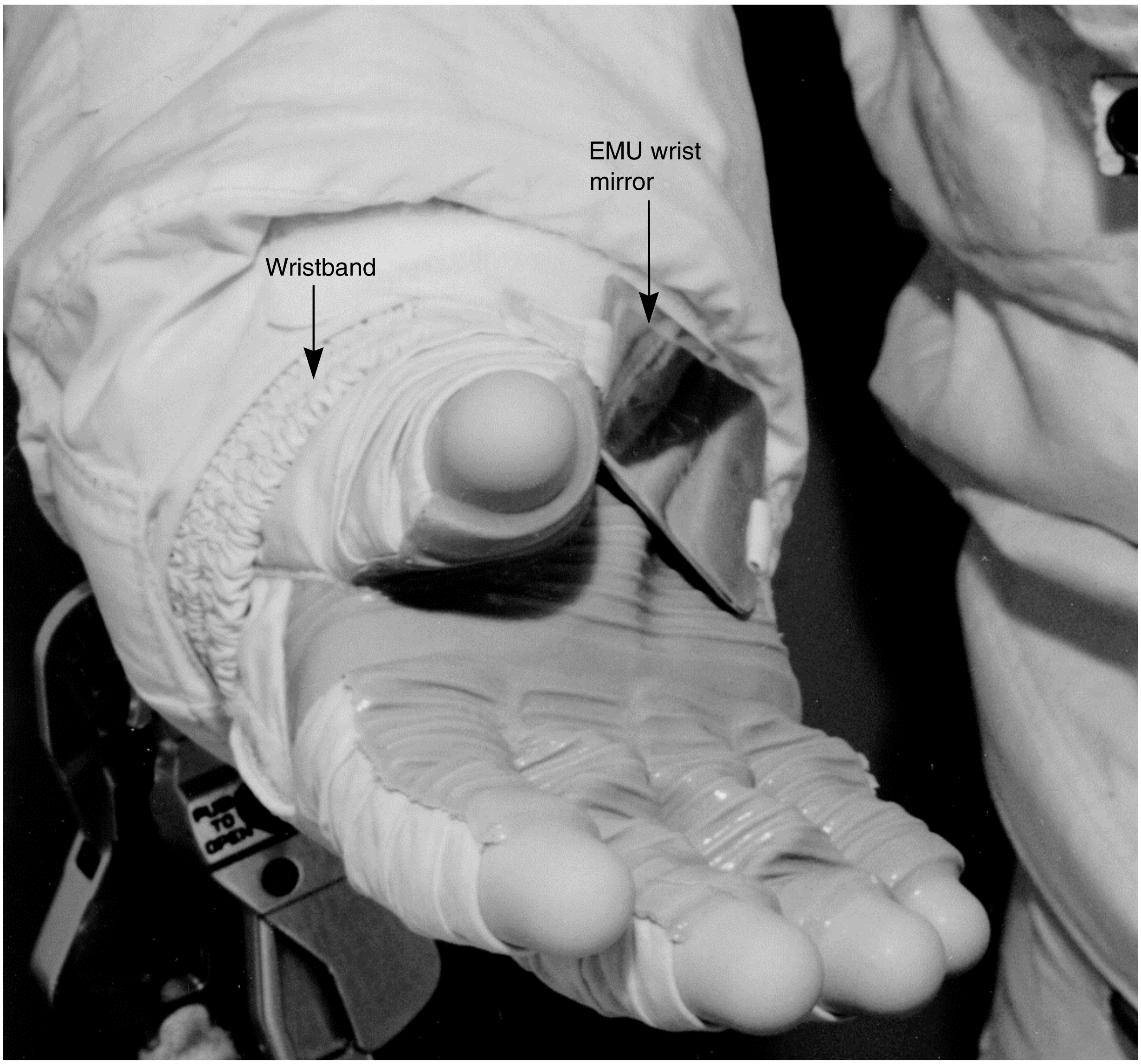

Figure 4-11. EMU wrist mirror

4.4 EVA Cuff Checklist

The EVA cuff checklist is a set of reference cards worn on the EMU lower arm; the cards contain procedures that aid in the diagnosis and resolution of EMU malfunctions (Figure 4-12). The checklist also contains procedures and reference data for performing EVA tasks.

The spiral-bound cards are approximately 4 by 5 inches in size. The binding connects to an aluminum alloy bracket, which in turn attaches to a wristband. Each card has an indexing tab for easy card location. The checklist is approximately 0.5 inch thick when closed. A limited number of pages can be added to the checklist for flight-specific EVA tasks.

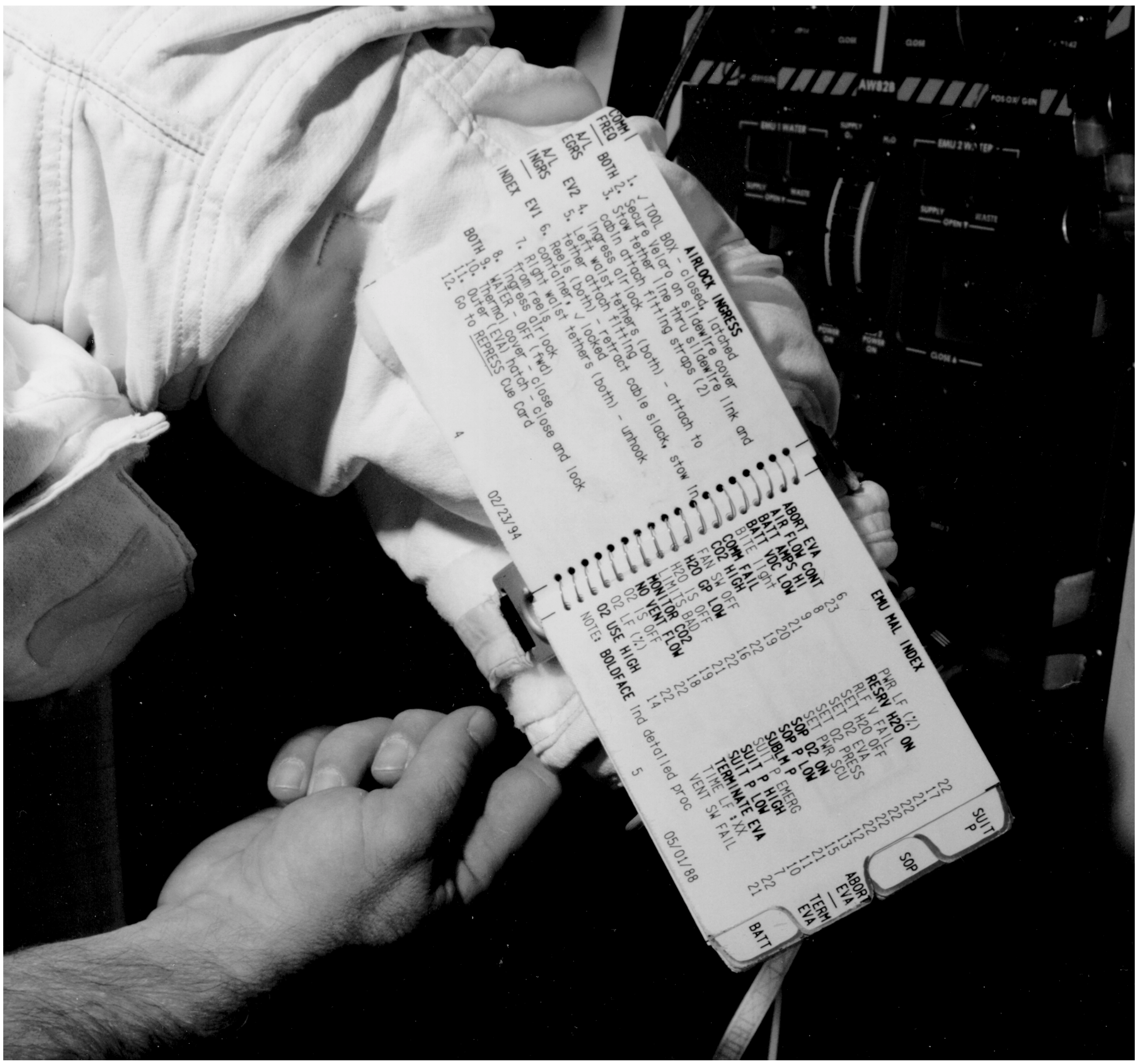

Figure 4-12. EVA cuff checklist

4.5 Mini-Workstation

The MWS is a mechanical device that mounts on the front of the EMU for tool stowage to provide a means of tether restraint for an EVA crewmember at a worksite (Figure 4-13). There is currently more than one version of the MWS. For detailed information on any of them, contact DX32/EVA Systems personnel for the following documents:

a. EVA Contingency Operations Training Workbook

b. EVA Tools and Equipment Reference Book (EVA Tool Catalog)

c. International Space Station EVA Tools Reference Book

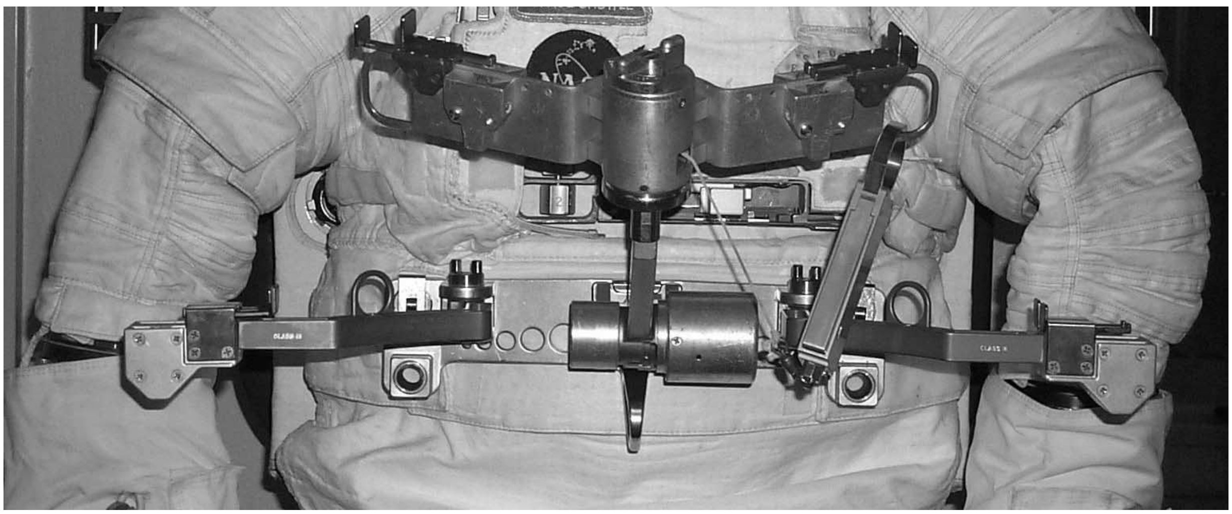

Figure 4-13. Mini-workstation

4.6 Adjustable Thermal Mitten Assembly

The Adjustable Thermal Mitten Assembly (ATMA) is a two-finger-and-thumb mitten worn over the EV glove that provides additional thermal protection for a crewmember's hands in extreme environmental temperatures (Figures 4-14 and 4-15). The EV gloves are designed to withstand contact temperatures from -180° to 235° F with a contact pressure of 1.0 psi for 30 seconds. The thermal mitten extends the range of allowable contact temperatures. A suited crewmember can don the mittens unassisted.

The ATMA construction is similar to that of a glove TMG (Teflon shell, insulation, liner, and RTV silicone gripping surface) and has an adjustable sizing cord that allows it to fit onto all EV glove sizes. The mitten interfaces to both the 4000 series and phase VI EV glove designs. The two-finger-and-thumb design of the ATMA provides complete surface protection while offering some type of limited crewmember mobility and functionality.

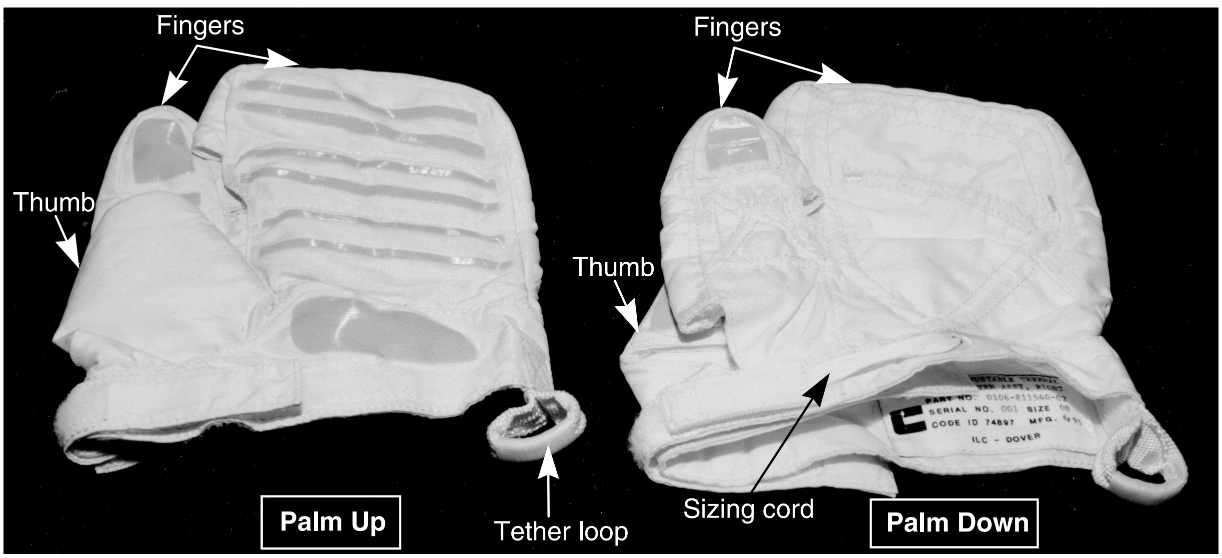

Figure 4-14. ATMA

Figure 4-15. Left ATMA on a suited crewmember

4.7 Waist Tether

The waist tether is used to attach the crewmember to the orbiter or ISS safety tether system and to provide additional crewmember restraint at a worksite when required. The waist tether consists of a strip of Nomex webbing material with a large aluminum EVA hook on one end and a small aluminum hook on the other end (Figure 4-16). The tether is attached to one of the two tether D-rings on the LTA. For detailed information on the waist tether and/or the hook types in use, contact DX32/EVA Systems personnel for the following documents:

a. EVA Contingency Operations Training Workbook

b. EVA Tools and Equipment Reference Book (EVA Tool Catalog)

c. International Space Station EVA Tools Reference Book

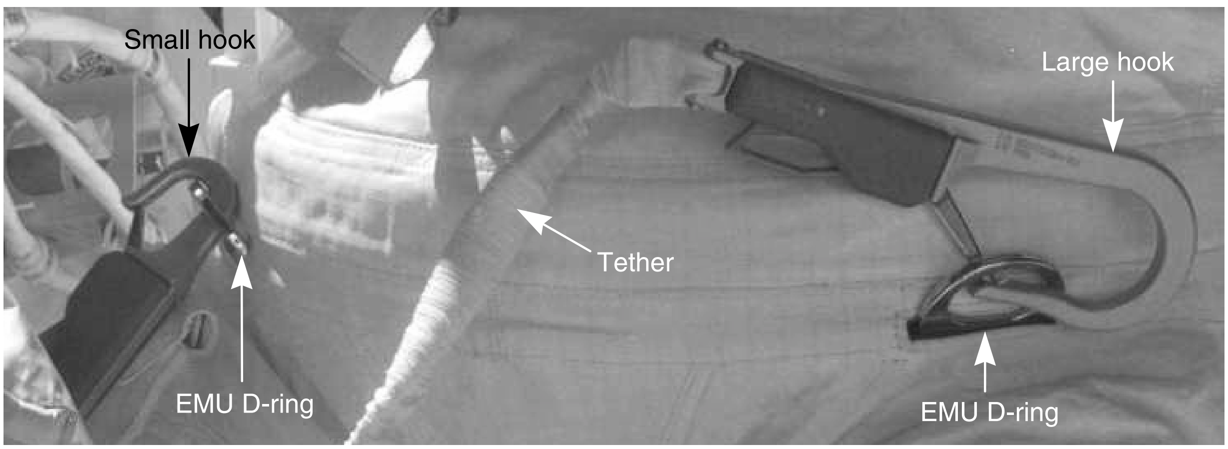

Figure 4-16. Waist tether

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4.8 Wrist Tether

The wrist tether is used to secure tools and hardware to the EVA crewmember and to tether points (Figure 4-17). The wrist tether consists of a strip of Nomex webbing material with a small aluminum EVA hook on each end. The tether attaches to loops on the EV gloves (Figure 4-18). For detailed information on the wrist tether, contact DX32/EVA Systems personnel for the following documents:

a. EVA Contingency Operations Training Workbook

b. EVA Tools and Equipment Reference Book (EVA Tool Catalog)

c. International Space Station EVA Tools Reference Book

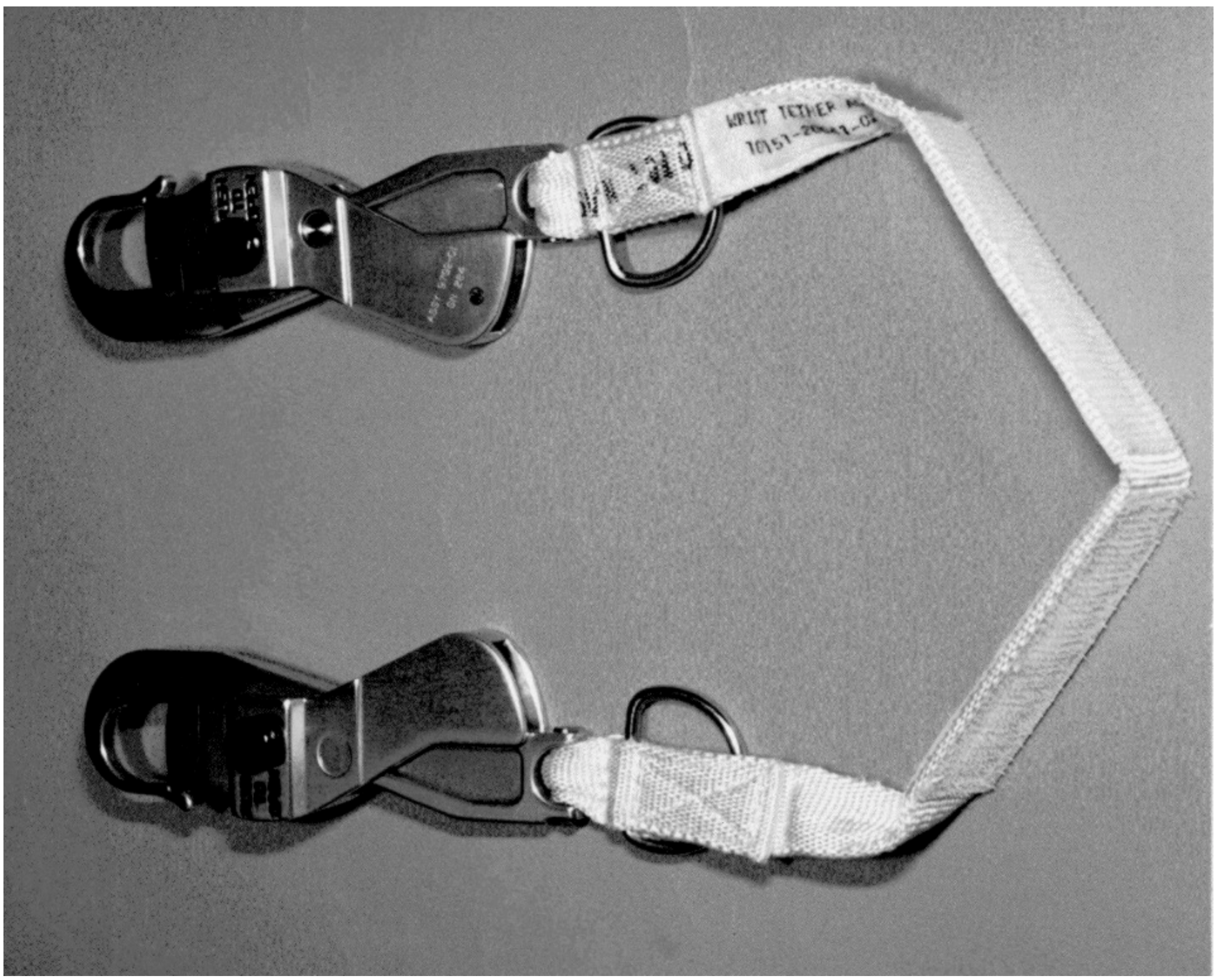

Figure 4-17. Wrist tether

Figure 4-18. Wrist tether attached to gloves

4.9 LTA Donning Handles

Two donning handles (left and right) help crewmembers mate the HUT and LTA halves of the waist ring (Figure 4-19). The handles slide into metal brackets on each side of the LTA waist ring. They lock in place by sliding the lock switch on the handle to the LOCK position. After use, they are unlocked, removed, and stowed. Care must be used not to pull outward on the handles during donning since they can be bent easily.

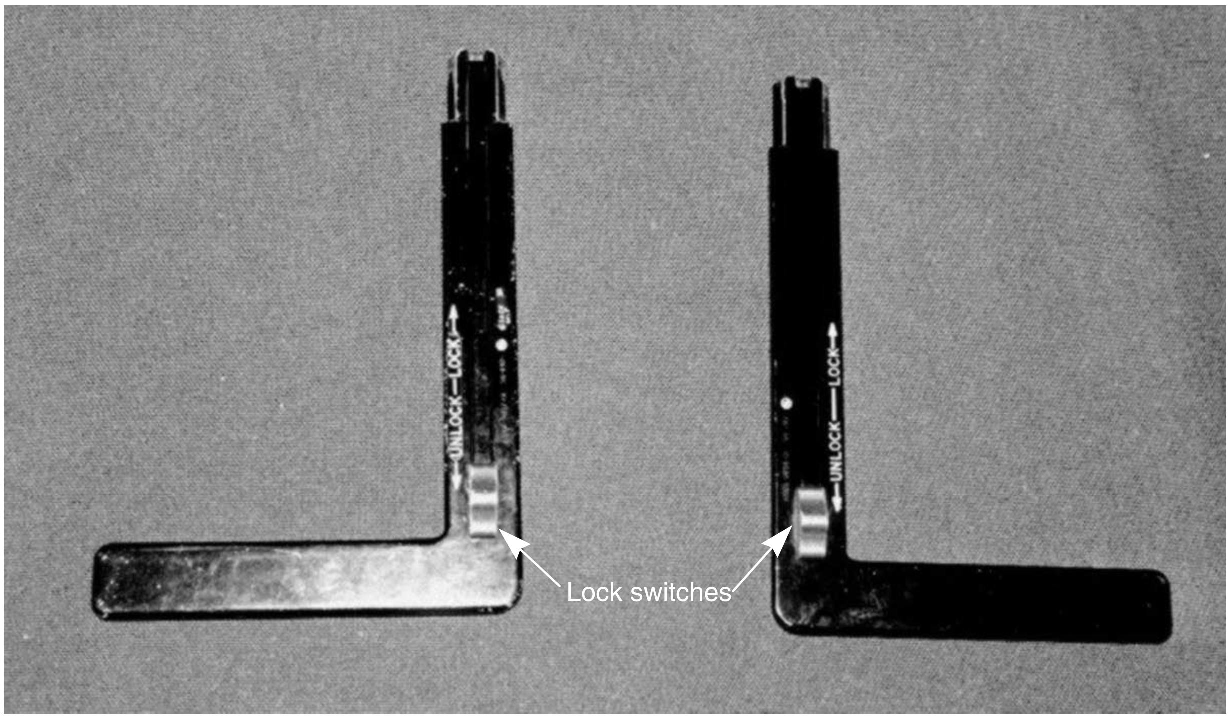

Figure 4-19. LTA donning handles

4.10 BSC Contingency Tool

The BSC contingency tool, often called the pry bar, is used to apply more leverage to the BSC doffing assist lever if the BSC latch mechanism becomes jammed. This can help to disconnect the LTA and HUT halves of the body seal closure so the crewmember can doff the EMU. Using the pry bar may damage the latch, so it should be used only if the crewmember is trapped in the EMU because of a jammed latch. Once the tool has been used with an LTA, that LTA is NO-GO for EVA.

The pry bar is a one-piece tool and consists of a handle and a rectangular socket (Figure 4-20). To use the tool, place the socket on the doffing assist lever and rotate the handle to the crewmember's left to move the locking handle from the ENGAGE to the OPEN position (Figure 4-21). The pry bar's additional leverage should allow the crewmember to overcome the jam and disengage the latch dogs.

Figure 4-20. BSC contingency tool (pry bar)

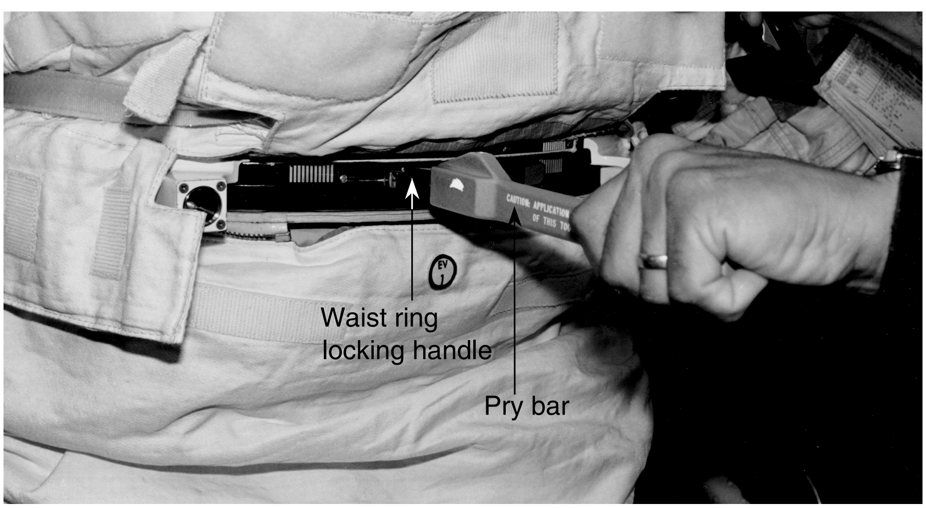

Figure 4-21. Use of the pry bar

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4.11 Bends Treatment Adapter

The Bends Treatment Adapter (BTA) is an emergency device that may be used on orbit in the event of decompression sickness (bends). The BTA (Figure 4-22) converts the EMU into a hyperbaric treatment chamber by allowing the EMU to be pressurized to 8.0 psid over ambient cabin pressure. If it is used in this manner, the EMU is NO-GO for subsequent EVAs and must be returned for ground servicing. The BTA consists of the following components:

a. Poppet keeper screw

b. Relief valve

c. Pressure gauge

d. Removal tool for BTA orifice cap on test port F

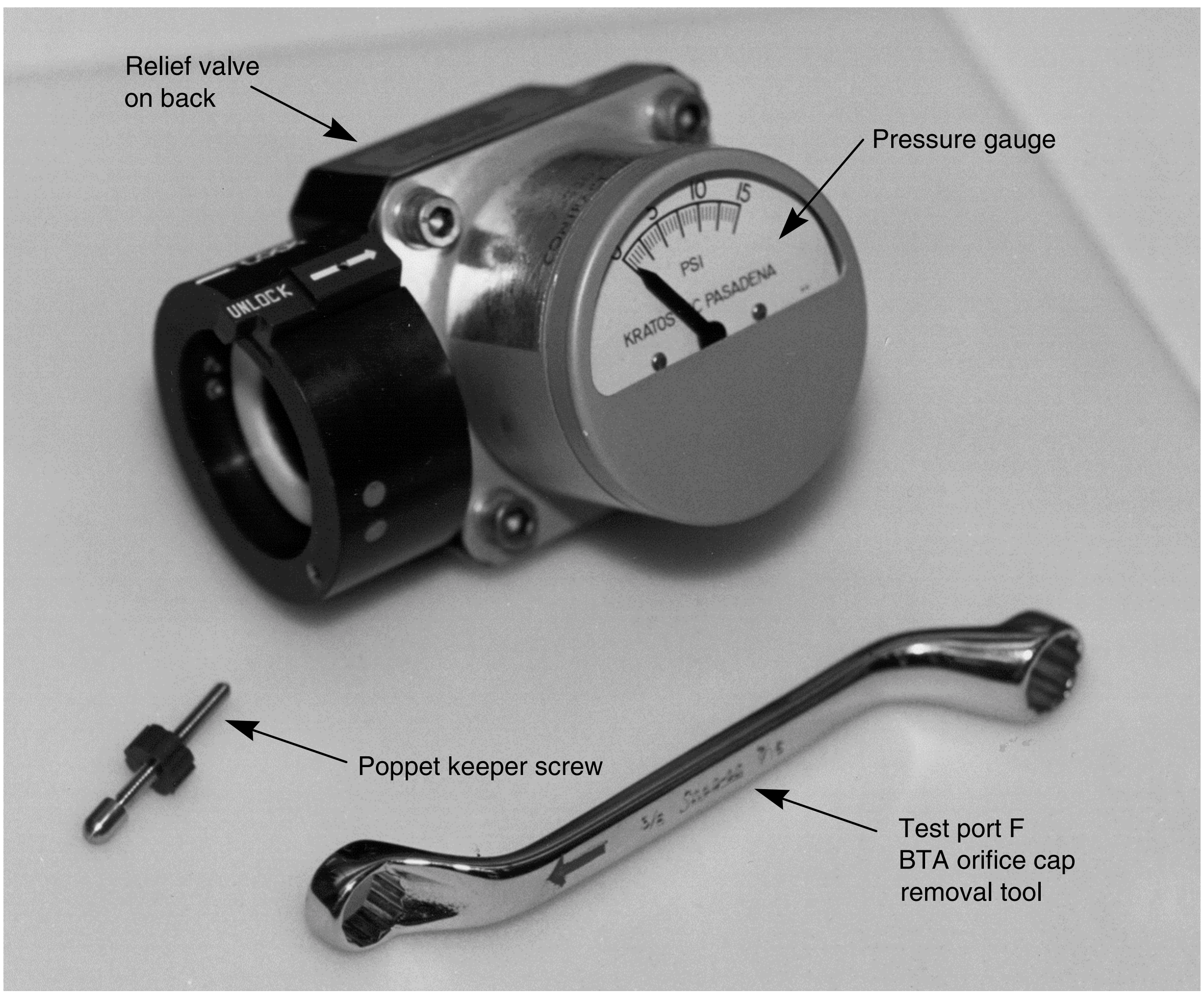

Figure 4-22. BTA

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The poppet keeper screw opens (overrides) the EMU Positive Pressure Relief Valve (PPRV), so that the BTA relief valve, when mounted over the PPRV, takes the place of the PPRV. This screw is stored in the housing of the BTA. The BTA relief valve allows for suit pressure of 8 psid because it begins to open at 8.04 psid. It is fully open at 8.45 psid. When fully open, the valve allows a flow of 7.57 lb/hr of O_2. The pressure gauge measures from 0 to 15 psig, with an error range of ±0.5 psig. Suit pressures above 6.0 psid are read with this gauge. The test port F BTA orifice cap removal tool on is a 3/8-inch open-end wrench that removes a cap over test port F on the SOP. This tool is contained with the BTA kit in a middeck locker.

The higher suit pressure is achieved by repeatedly filling the gas side of the primary water tanks to 15 psid and dumping that gas into the EMU. Each cycle of dumping O_2 into the SSA raises the suit pressure approximately 0.5 psid, and the cycles are repeated until a suit pressure of 8.0 psid is reached.

Referencing the EMU schematic (SSSH Drawing 21.10) will help explain how BTA operations are performed. First, the poppet keeper screw and the BTA relief valve are installed on the PPRV (Figures 4-23 to 4-25), then the test port F orifice cap is removed (Figure 4-26). Second, the affected crewmember dons the EMU; the EMU is purged of N_2, and the water tanks are dumped. Third, to pressurize the water tank bladders, the O_2 actuator is cycled to the PRESS position. In the PRESS position, the primary O_2 shutoff valve is open, the suit is pressurized to 4.3 psid, and the water pressure regulator flows 15.0 psid O_2 into the water tank volume. Finally, the O_2 actuator is moved to the OFF position, which closes the O_2 shutoff valve and allows the lines pressurizing the water tanks to bleed down through the BTA orifice in test port F (Figure 4-26). The Low Mode Relief Valve (LMRV) senses a low pressure upstream of the check valve and opens, venting the O_2 in the water tanks through the low mode relief valve, to the T-11 port, into the SSA, thus increasing suit pressure. When the suit pressure stabilizes, the O_2 actuator is moved back to PRESS to repeat the process until a suit pressure of 8.0 psid is obtained. This treatment regimen is maintained under guidance of the MCC surgeon.

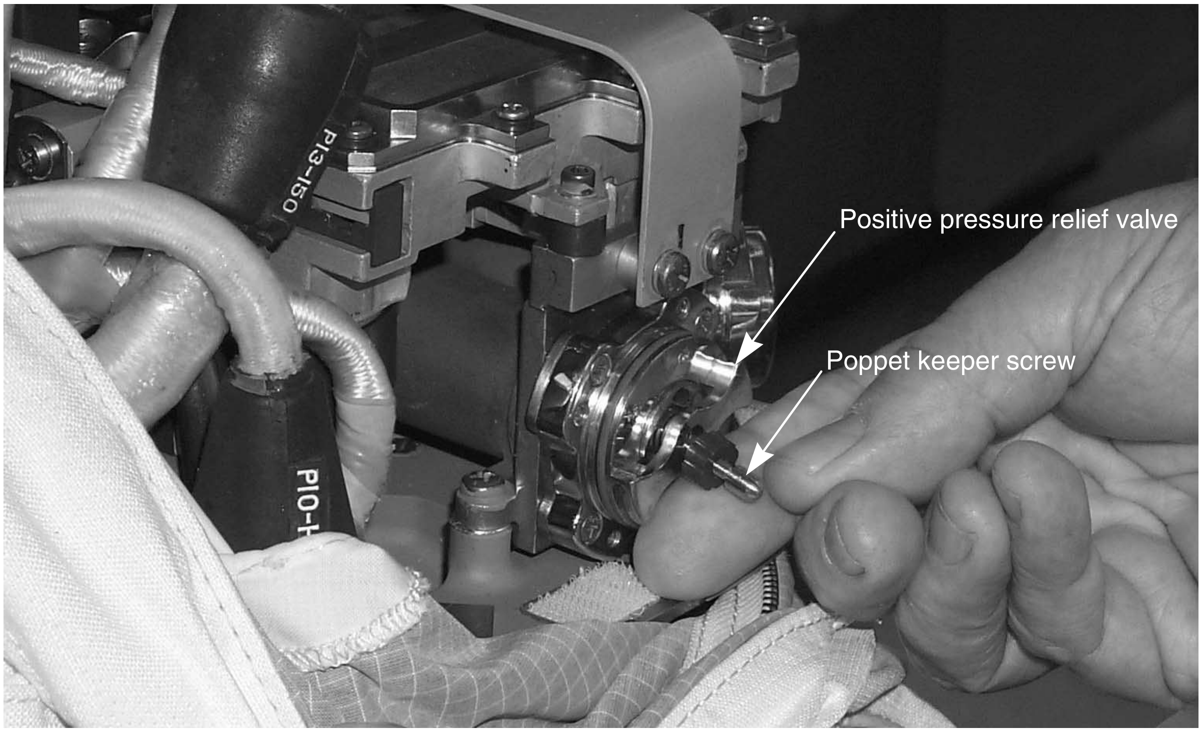

Figure 4-23. BTA poppet keeper screw installation

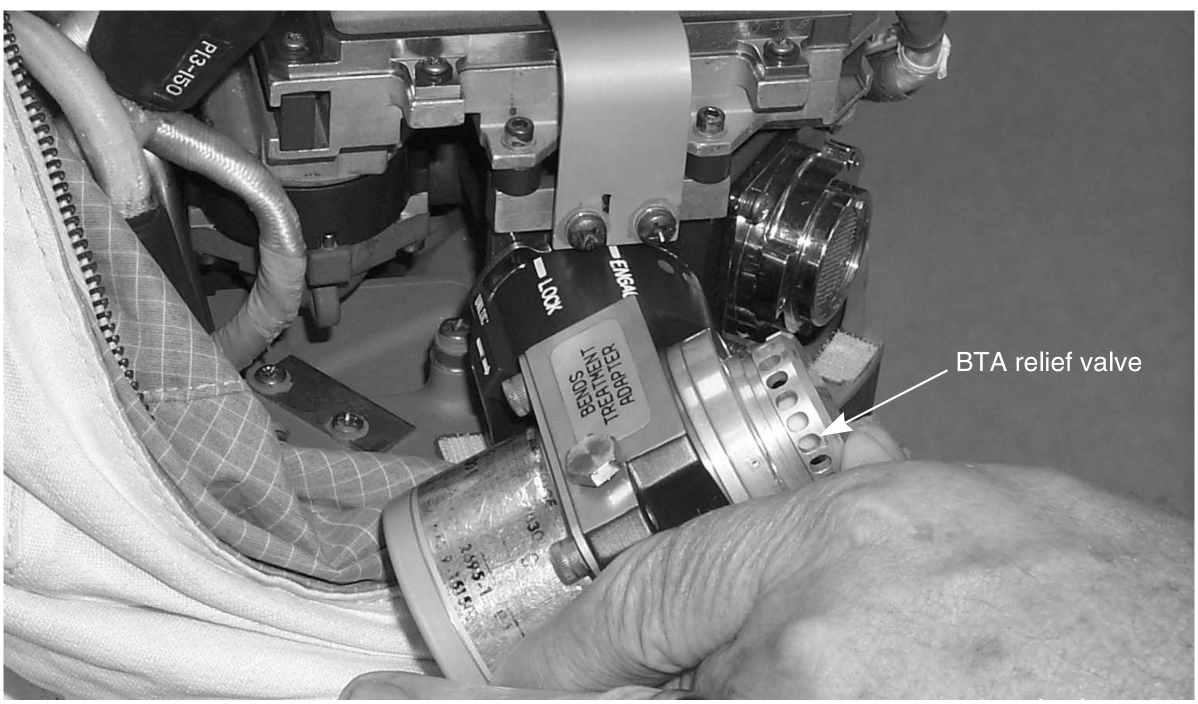

Figure 4-24. BTA relief valve installation (engaged position)

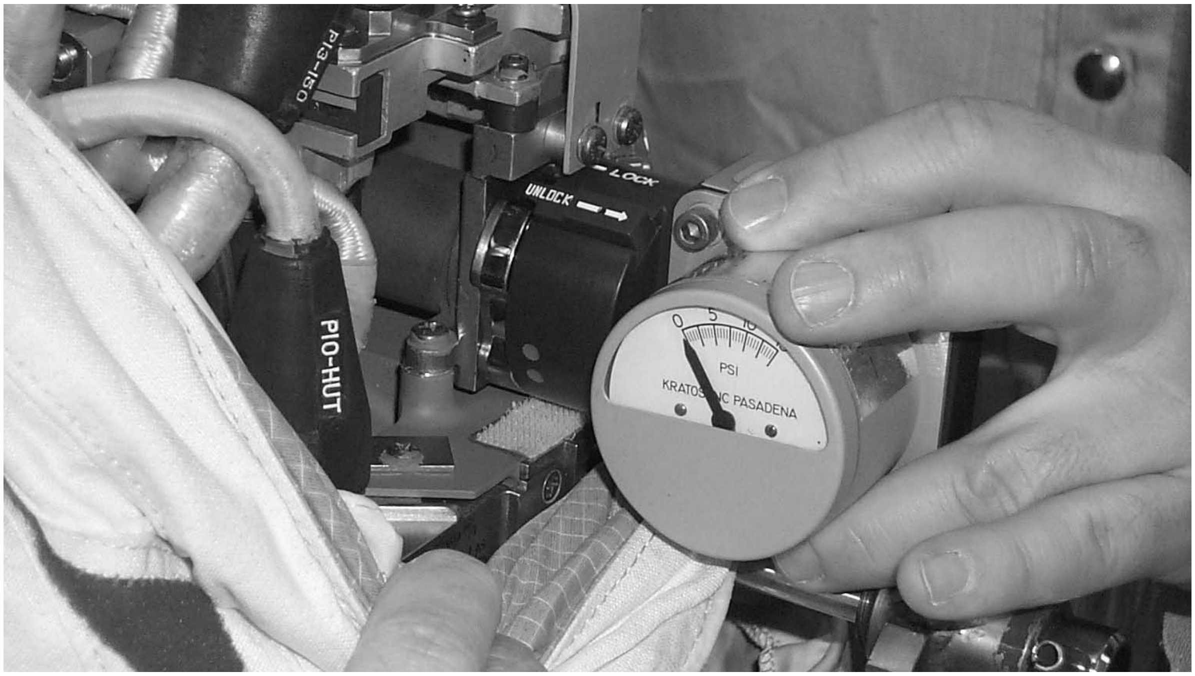

Figure 4-25. BTA relief valve installation (locked position)

Figure 4-26. Test port F location on front of SOP

During BTA operations, the SCU provides oxygen and electrical power; the PLSS fan/pump/water separator provides ventilation flow for CO_2 washout from the facial area and water flow for cooling; and the CCC provides CO_2 removal.

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4.12 SOP Checkout Fixture

The SOP Checkout Fixture (SCOF) is used both on the ground and on orbit to verify SOP, fan, and vent flow sensor operation, as well as aiding with the water dump procedure. The SCOF consists of a bowtie-shaped fixture plate with an attached relief valve (Figure 4-27). The SCOF functionally replaces the SOP checkout package in the PLSS because of corrosion problems that made the relief valve of the checkout package unreliable.

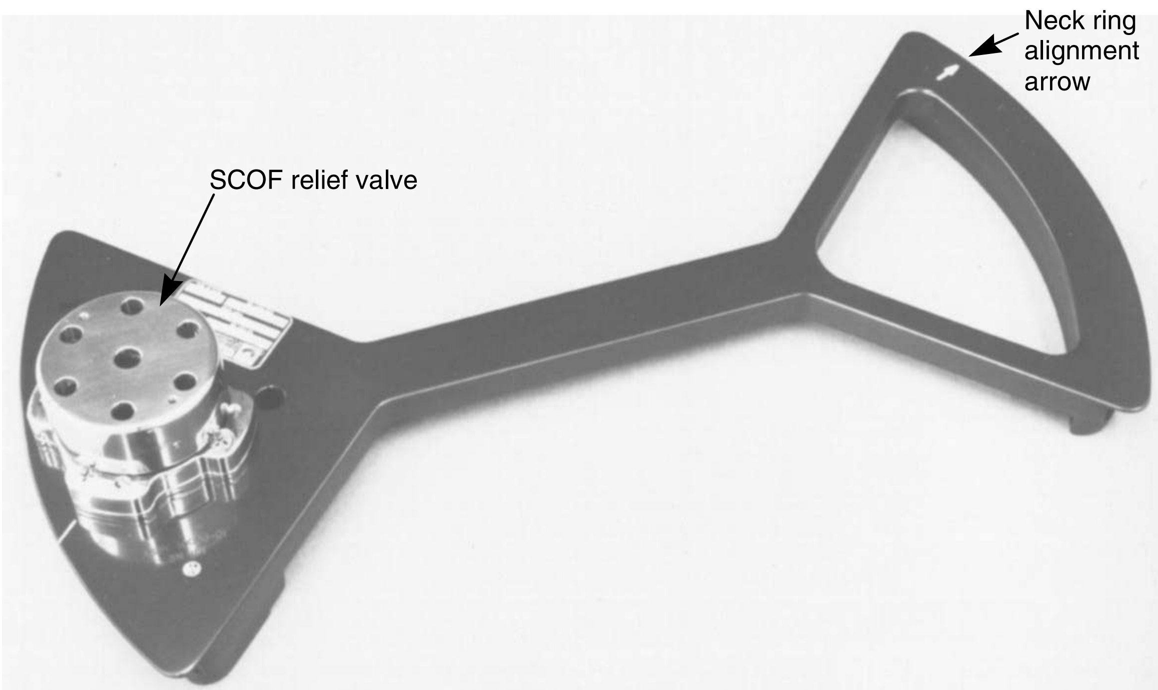

Figure 4-27. SCOF

The SCOF mounts on the HUT half of the helmet neck ring to cover the oxygen vent duct (Figure 4-28). This seals the vent loop between the SCOF and the vent flow sensor/backflow check valve, except for a small amount of flow through the CO_2 sensor, which places a small demand on the SOP regulators. This allows that circuit to be pressurized across the suit pressure sensor without assembling the entire EMU and pressurizing the SSA. With the vent circuit pressurized, the SOP, fan, and vent flow sensor can all be checked, and water dumps can be performed.

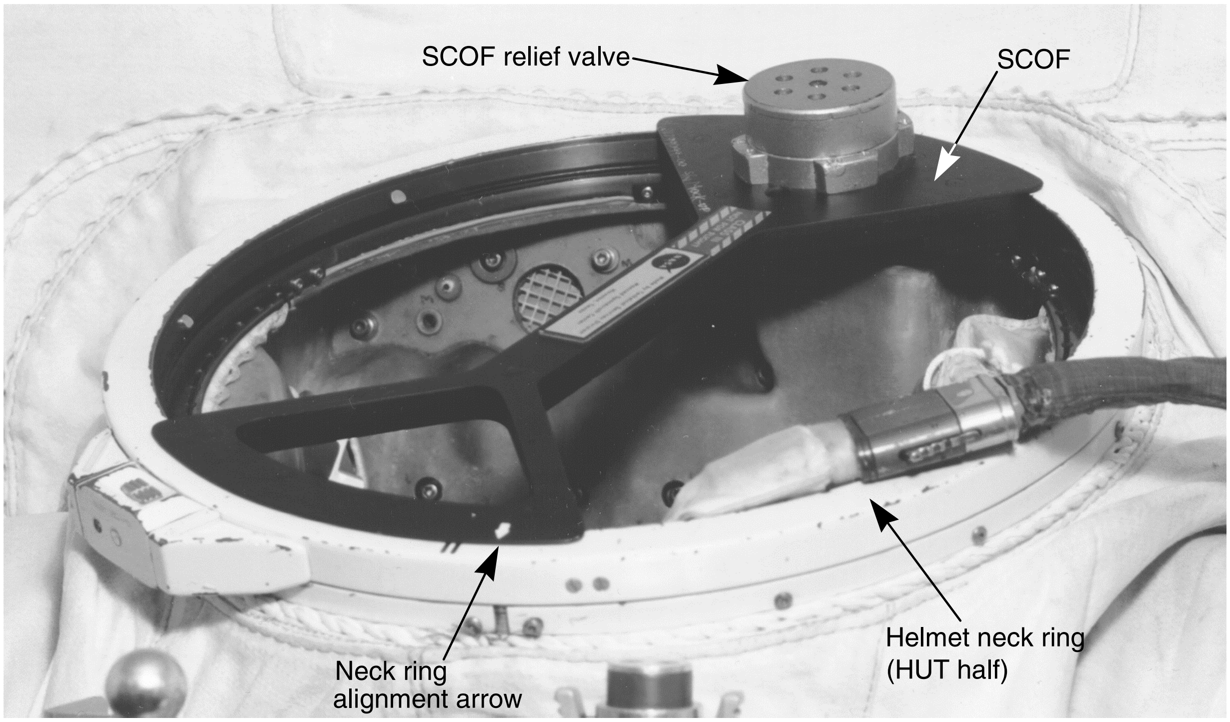

Figure 4-28. SCOF mounted on neck ring

The fixture plate has an arrow on top that aligns with markings on the neck ring. This arrow ensures proper alignment with the vent duct. Grooves on the fixture plate allow the neck ring latching pins to hold the SCOF in place when the neck ring latch is moved to the LOCKED position.

The relief valve is similar to the PPRV and provides overpressure protection for the EMU in case the SOP first- and/or second-stage oxygen regulators fail open during SOP checkout. It begins to open at 4.75 psid and, when fully opened at 5.5 psid, flows 7.49 lb/hr of dry O_2.

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4.13 DCM Plug

The DCM plug attaches to and covers the multiple connector on the DCM (Figures 4-29 and 4-30). This is necessary if water starts to leak from the DCM water ports when the SCU is removed. The plug, constructed from an SCU multiple connector, seals the DCM water ports. It also seals the O_2 port and covers the electrical connector on the DCM.

Water may leak from the ports if the poppet seals on the ports do not reseat when the SCU is disconnected. When used, the DCM plug remains attached to the DCM throughout the EVA. It is removed just before the SCU is connected, after airlock ingress.

Figure 4-29. DCM plug, front view

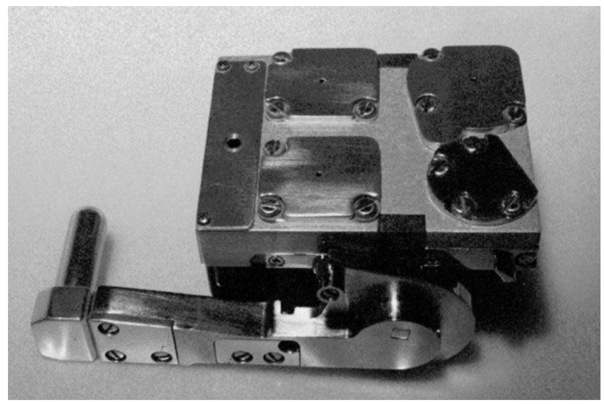

Figure 4-30. DCM plug, back view

4.14 Prep Kit

The prep kit contains items necessary for preparing the EMU for EVA (Figure 4-31). These items include:

a. Antifog wipes (12)

b. Package of tissue-type wipes (54)

c. Scissors with a lanyard

d. UCD clamps (6)

The prep kit is snapped inside the center back pocket of the EMU equipment bag.

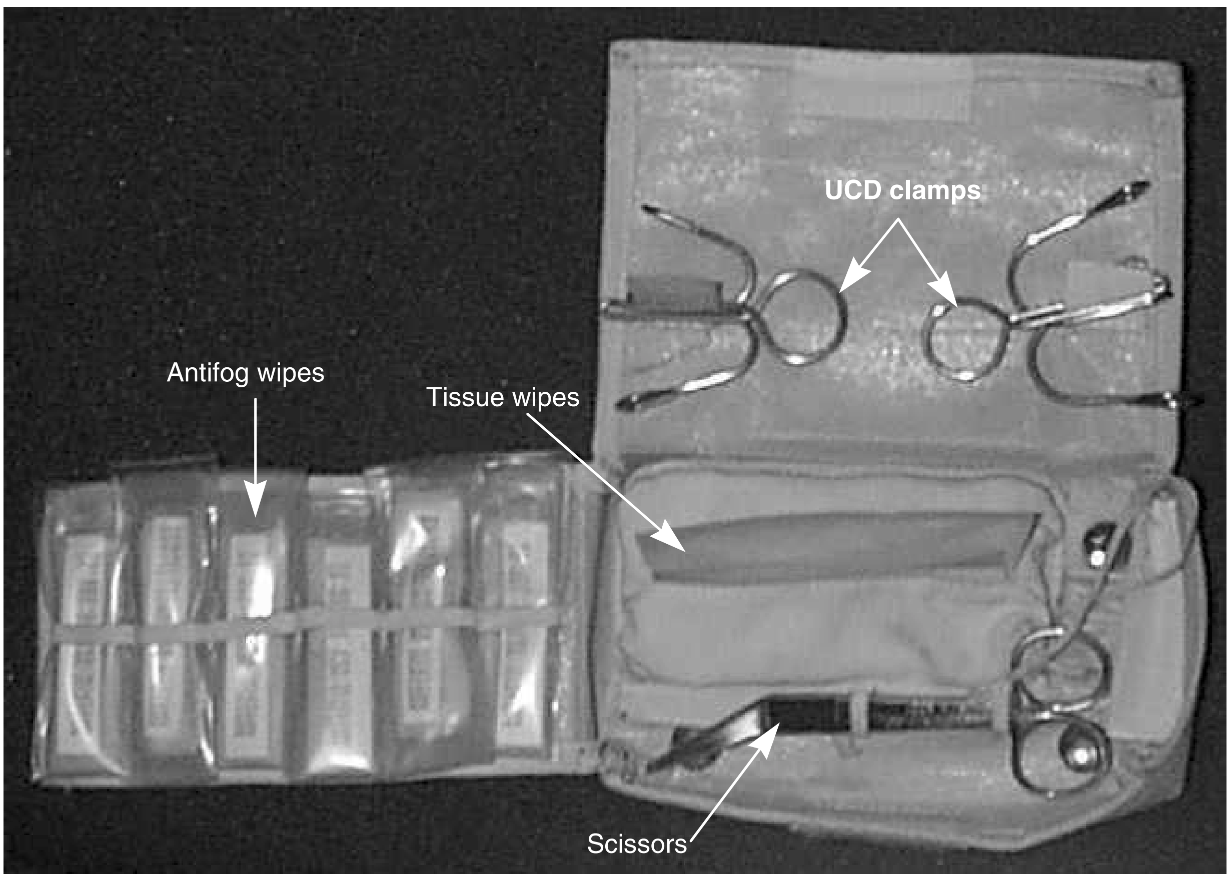

Figure 4-31. Prep kit

4.15 Maintenance Kit

The maintenance kit contains equipment necessary for routine and contingency EMU maintenance (Figure 4-32). This equipment includes:

a. Valsalva devices (8)

b. Stericide wipes (20)

c. Lubricant wipes (16)

d. Antifog wipes (8)

e. UCD roll-on cuffs (12)

f. SOP thermal cover lacing cord and needle

g. Extra BTA poppet keeper screw

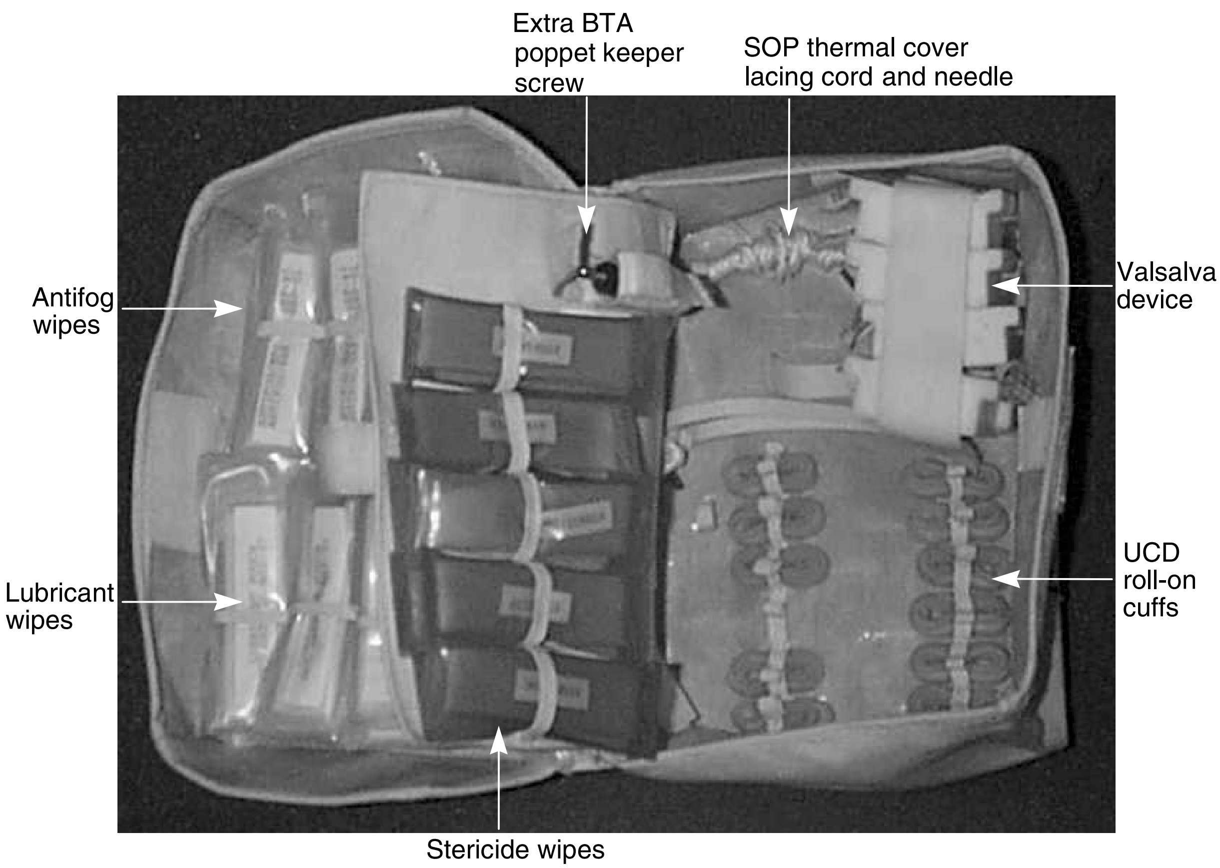

Figure 4-32. Maintenance kit

Valsalva devices are discussed in Section 5.6. After each EVA, the crotch area of the EMU is wiped with a stericide wipe to prevent bacteria growth. Lubricant wipes are no longer used. Antifog wipes are used during Middeck Prep to help prevent fogging of the helmet. The UCD is discussed in Section 2.11. The SOP thermal cover lacing cord and needle are included in case it is necessary to switch an SOP from one EMU to another. An extra BTA poppet keeper screw is included in case the one stowed on the BTA relief valve housing is lost. Another configuration of the maintenance kit that can be flown, but usually is not, includes tools for SOP changeout.

4.16 Bio Kit

The bio kit contains equipment used with the OBS (refer to Section 2.7).

4.17 EMU Equipment Bag

The EMU equipment bag, formerly the airlock stowage bag, is made of Nomex and is used to temporarily stow items used in pre- and post-EVA operations (Figure 4-33). It has several elasticized pockets with labels and Velcro closures. These pockets are of various sizes and hold the following:

a. EV gloves

b. Comm caps

c. In-suit drink bags

d. In-suit drink bag syringe

e. Eyeglasses

f. EVA cuff checklists

g. Trash

h. LTA donning handles

i. DCM plug

j. Thermal mittens

k. Comfort gloves and wristlets

l. BSC contingency tool

m. SOP checkout fixtures

n. Prep kit

Figure 4-33. EMU equipment bag

A strap and a pip pin are on each side of the bag for mounting the bag on the forward middeck lockers (Figure 4-34). The bag may also be attached inside the airlock over the inner hatch, but it must be removed from the airlock prior to airlock depressurization.

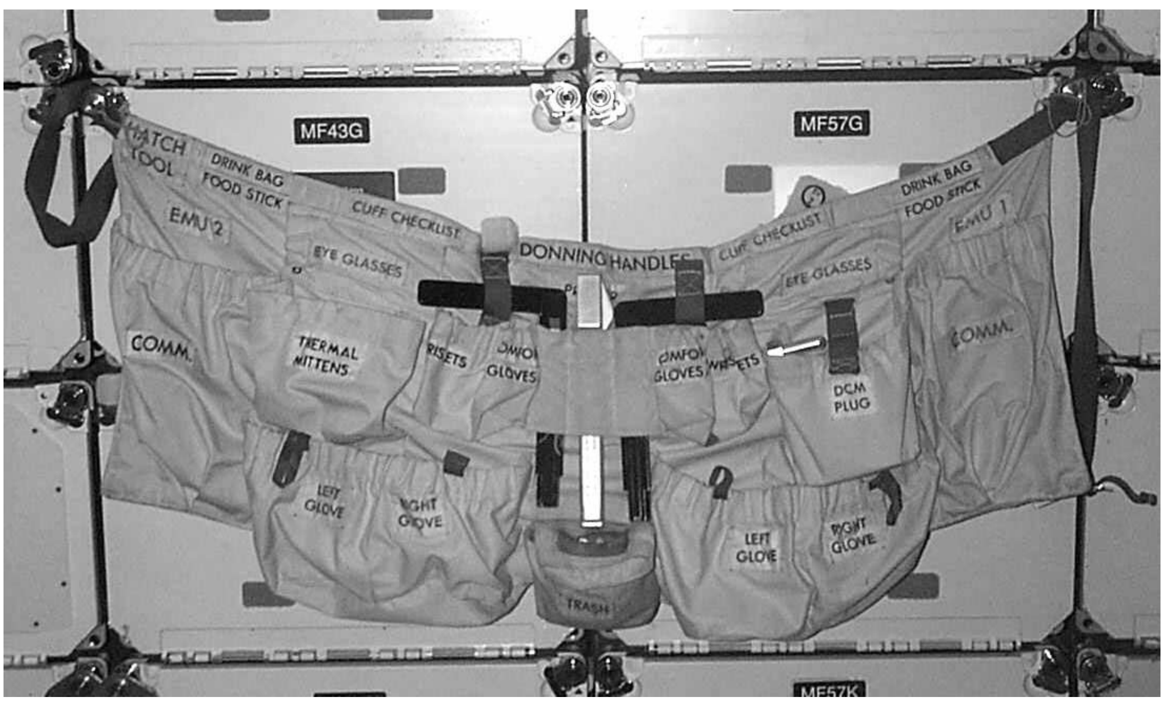

Figure 4-34. EMU equipment bag mounted on middeck lockers

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4.18 EVA Bag

The EVA bag is placed in the airlock to hold items that may be needed during EVA (Figure 4-35). It is made of Nomex and has several elasticized pockets with labels and Velcro closures. These pockets are of various sizes and store the following:

a. Camera

b. Thermal mittens

c. Tool caddy

d. DCM plug

e. Contingency airlock hatch tools

f. EVA cue cards

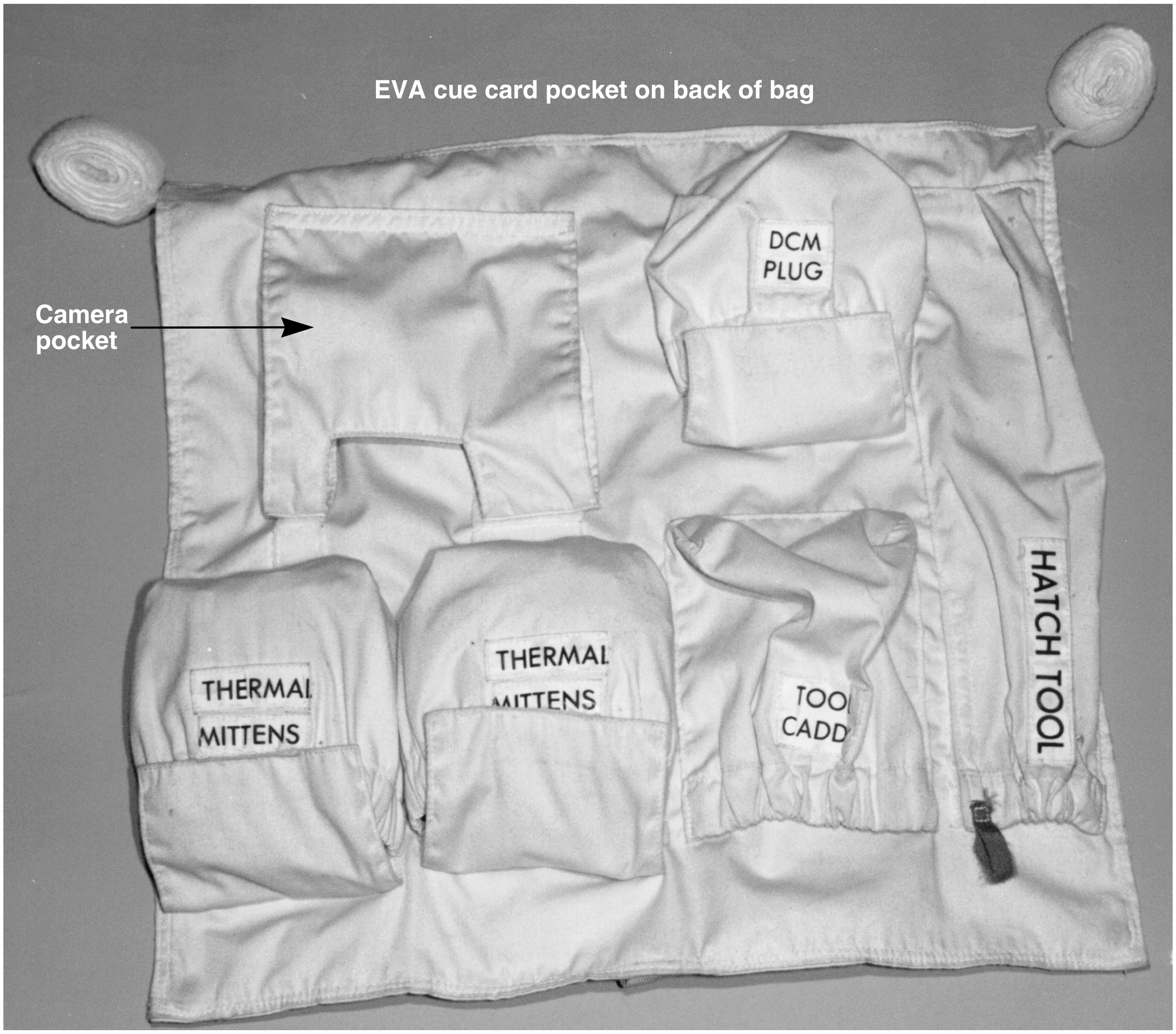

Figure 4-35. EVA bag

The EVA bag has snap and Velcro attachment points. During the EVA prep period, the bag is attached to the airlock inner wall, over the outer hatch, with four snaps. If the bag needs to be placed elsewhere, there is one 27.5-inch Velcro strap coiled at each top corner of the bag. These straps can be used to tether the bag where it is needed.

4.19 Simplified Aid for EVA Rescue

The Simplified Aid for EVA Rescue (SAFER) provides contingency self-rescue capability for a separated EV crewmember if an orbiter is not able to provide rescue (Figure 4-36). It is a small, self-contained propulsive backpack that mounts on the PLSS. Twenty-four gaseous nitrogen thrusters provide six degrees of freedom for maneuvering back to a secure location. A Hand Controller Module (HCM) deploys from the backpack and mounts to the DCM to provide maneuvering control. For detailed information on the SAFER, contact DX32/EVA Systems personnel for the following documents:

a. USA Simplified Aid for EVA Rescue Operations Manual

b. EVA Tools and Equipment Reference Book (EVA Tool Catalog)

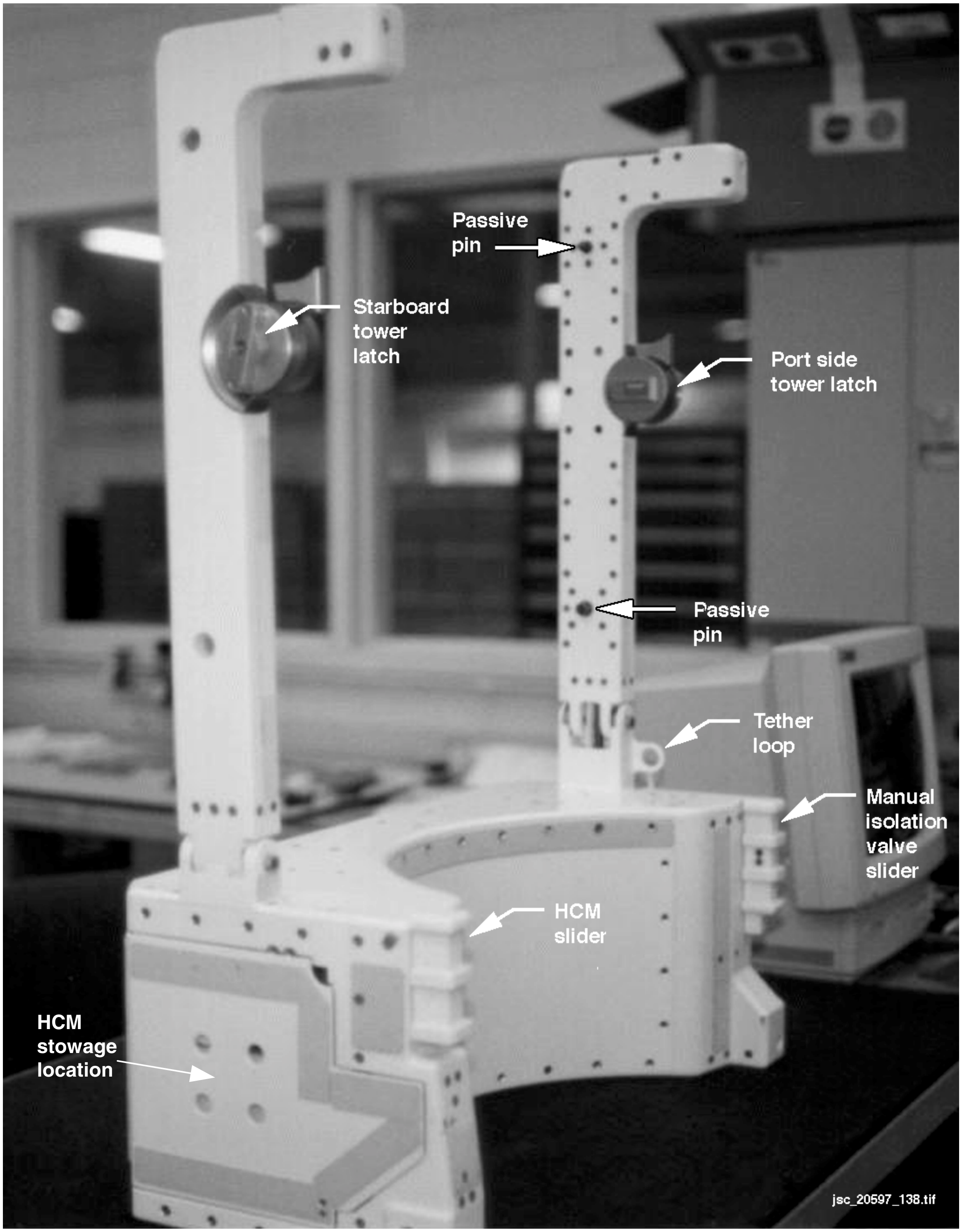

Figure 4-36. SAFER with TMG removed

Section 5
Crew Options

EV crewmembers have several items available to help make the EMU comfortable to wear and operate. These items include:

a. Comfort pads

b. Thermal comfort undergarments

c. Socks/sock liners

d. Comfort gloves

e. Wristlets

f. Valsalva devices

g. Fresnel lenses

5.1 Comfort Pads

The types of comfort pads that can be worn by the crewmember include:

a. Shoulder pads (Figure 5-1)

b. Rib pads

c. Knee pads

d. Back pads

e. Stabilization pads

f. Elbow pads

g. Heel pads

h. Knuckle pads

i. Moleskin

Figure 5-1. Shoulder pad location

The shoulder pads are attached to the outside of the LCVG. Three types of shoulder pads can be used. The first is a generic pad used for general shoulder comfort. The second type of pad provides specific padding to prevent the scye bearing from rubbing on the shoulder. The third shoulder pad covers the chest and collar bone areas.

The rib pads are attached to the outside of the LCVG, under the arm. This protects the rib area from abrasion by the scye bearing during arm motion if the HUT fits snugly.

Kneepads are normally worn while training on the ground. During EVA training in the water facilities, crewmember body weight often rests on the knees because of the orientation of the crewmember in the EMU. The kneepads ease this load.

Back pads help stabilize the crewmember in the EMU if there is space between the back of the HUT and the crewmember's back. The thickness of the pad can be changed for each crewmember.

Stabilization pads fit into the crotch area to boost crewmembers higher in the HUT and helmet during ground training. This gives better visibility because it overcomes the force of gravity pulling the crewmember down into the LTA.

Elbow pads prevent a crewmember's elbows from chafing on the inside of the EMU arm. As the EMU is designed, the crewmember's elbows will be in constant contact with the suit arm, so these pads are used. They can be sized for each crewmember.

Heel pads allow a crewmember's feet to fit snugly into the EMU boot. The EMU boot heels are all the same size. If the boot is loose, it can be difficult to ingress the portable foot restraints used during EVA. The pads ensure a correct boot fit.

Knuckle pads help prevent chafing of the crewmember's hand on the EMU glove. The gloves fit snugly and are in almost constant motion, which can cause considerable irritation. The pads are made of moleskin and a spongy material and can be sized for each crewmember.

Moleskin helps prevent chafing in any other body locations. It is a thin, synthetic, padded material with adhesive on one side that sticks to a crewmember's skin. Contact between the EMU and a part of the body is unavoidable and can change from one crewmember to the next, so moleskin is used as necessary. Often moleskin is used above the elbow on the "funny bone" and on fingers.

5.2 Thermal Comfort Undergarments

Thermal Comfort Undergarments (TCUs) may be worn under the LCVG to help keep the crewmember warm during EVA and/or prevent the LCVG liner from making the skin itch. The TCUs include pants and a long-sleeved shirt, which are made from lightweight thermal underwear (Figure 5-2).

Figure 5-2. Thermal comfort undergarments

5.3 Socks/Sock Liners

Crewmembers have the option to wear two different kinds of socks in the EMU. The options are tube or crew socks. Both are made of cotton.

5.4 Comfort Gloves

Comfort gloves are worn if a crewmember wants an added measure of comfort inside the EV glove assembly (Figure 5-3). Crewmembers can choose from three different types of comfort gloves: thick woven spectra, thin woven spectra, and sewn nylon. Each type comes in numerous sizes. Comfort gloves worn under the EV glove help in donning, doffing, and controlling perspiration. They also provide a comfortable layer of fabric between the hand and the EV glove bladder.

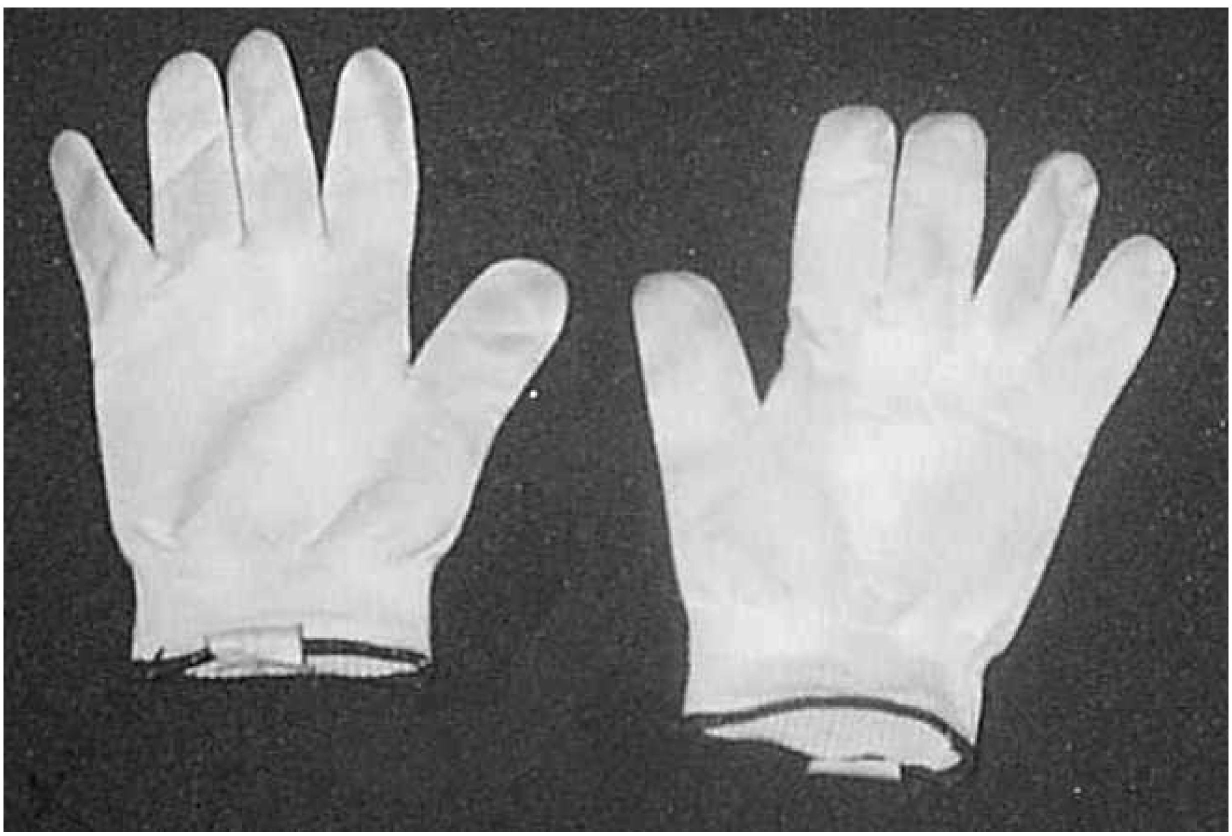

Figure 5-3. Comfort gloves

5.5 Wristlets

Wristlets protect a crewmember's wrists from the EMU glove disconnect and glove gimbal ring (Figure 5-4). They are made of heavy cotton similar to the "tube" section of athletic socks.

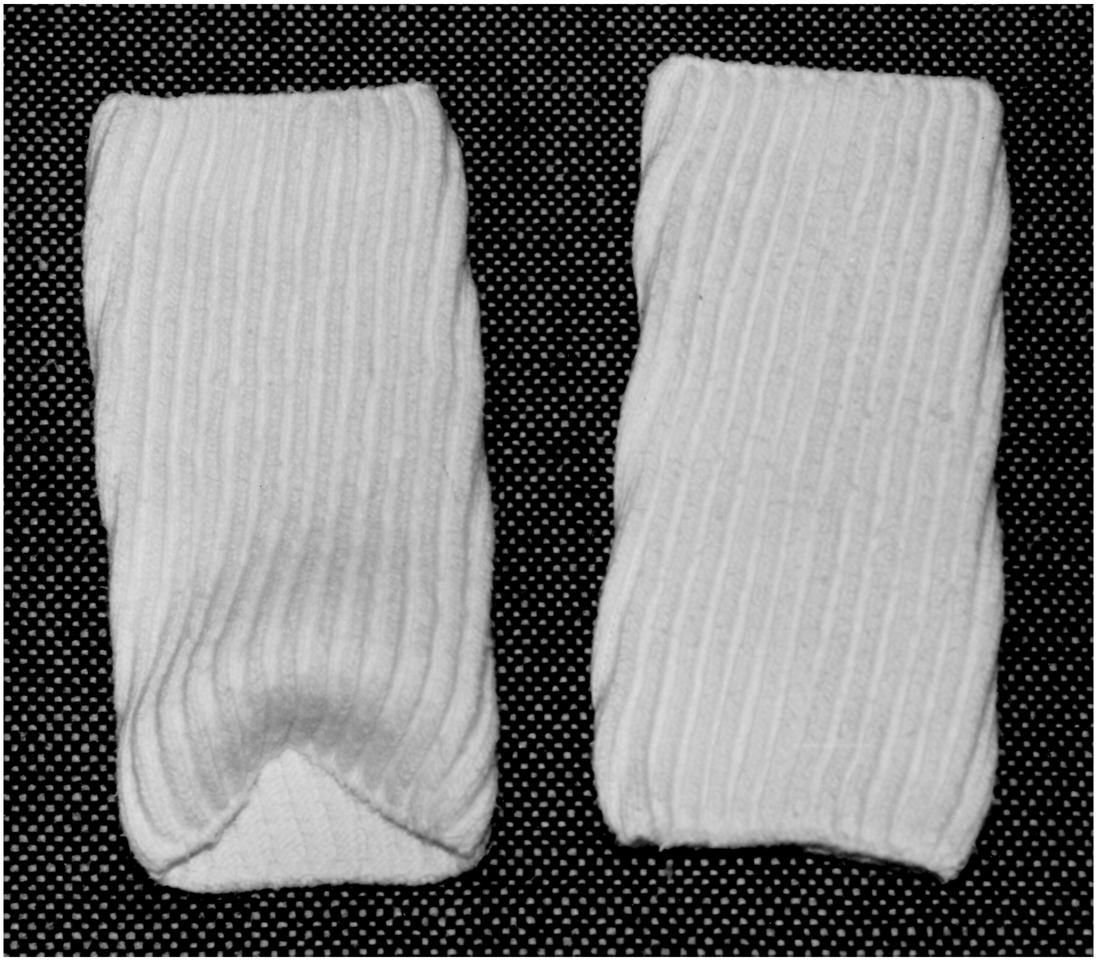

Figure 5-4. Wristlets

5.6 Valsalva Device

The Valsalva device can be attached to the inside of the helmet with pressure sensitive adhesive (Figure 5-5). Crewmembers can clear their ears during pressure changes by performing the Valsalva maneuver, which is done by pressing the nostrils against the device and exhaling through the nose.

5.7 Fresnel Lens

The Fresnel (pronounced “freh-nel”) lens can be mounted to the inside lower front of the helmet bubble (Figure 5-5). This magnifying lens helps the crewmember see the DCM labels and display.

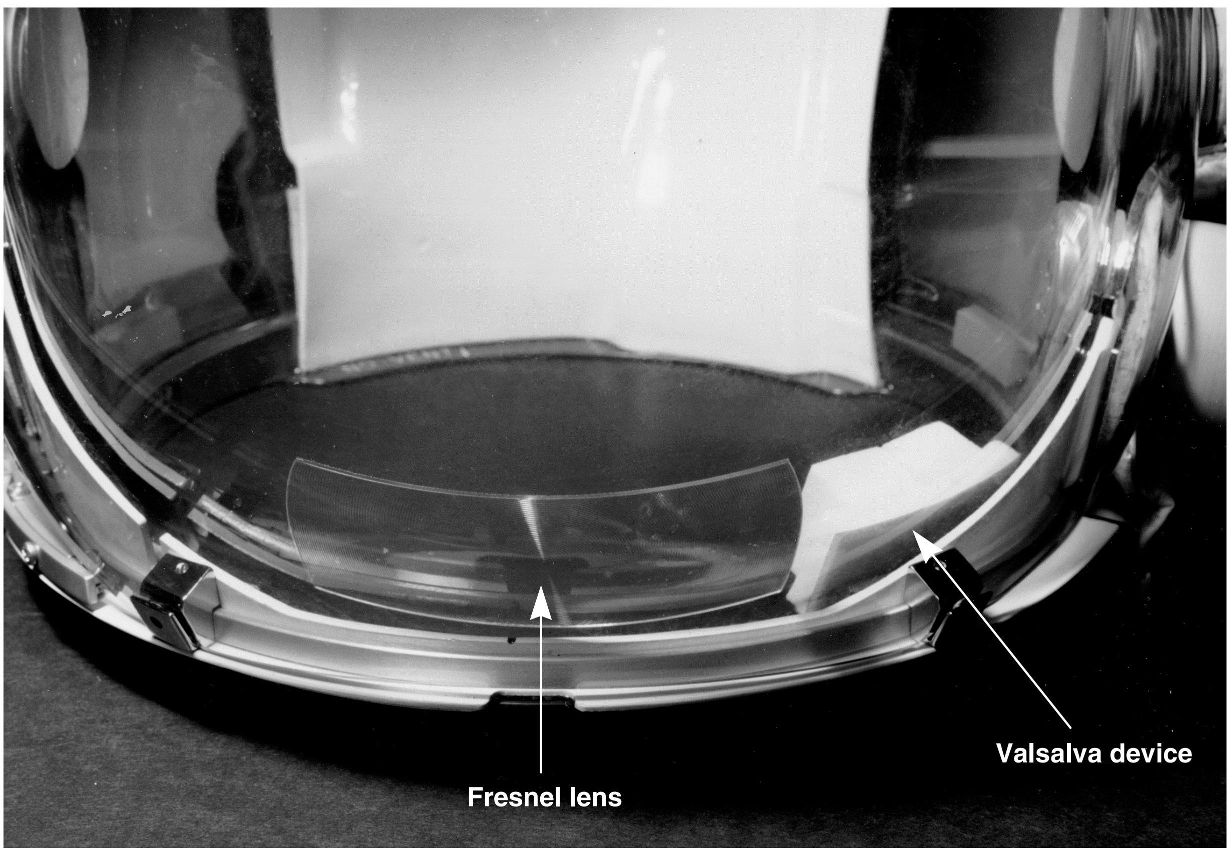

Figure 5-5. Valsalva device and Fresnel lens

Appendix A
Acronyms and Abbreviations

AAH	Automatic Attitude Hold
AAP	Airlock Adapter Plate
ALPS	Airlock Power Supply
ASCC	Advanced Solar Control Cooling
ATMA	Adjustable Thermal Mitten Assembly
ATU	Audio Terminal Unit
BITE	Built-In Test Equipment
BSC	Body Seal Closure
BTA	Bends Treatment Adapter
CCA	Communications Carrier Assembly
CCC	Contaminant Control Cartridge
CEA	Control Electronics Assembly
COMM freq	Communication frequency
CPV	Combination Purge Valve
CWS	Caution and Warning System
DCM	Display and Control Module
DIDB	Disposable In-Suit Drink Bag
DTO	Detailed Test Objective
ECG	Electrocardiogram
ECLSS	Environmental Control and Life Support System
EEH	EMU Electrical Harness
EMU	Extravehicular Mobility Unit
EPROM	Erasable Programmable Read-Only Memory
EV	Extravehicular
EVA	Extravehicular Activity
EVVA	Extravehicular Visor Assembly
GP	Gas Pressure
GSE	Ground Support Equipment
HCEA	Hand Controller Electronics Assembly
HCM	Hand Controller Module
HCU	Hand Controller Unit
HL	Hardline
HTS	Hard Torso Shell
HUT	Hard Upper Torso
ICB	Increased Capacity Battery
IDB	In-Suit Drink Bag

ISS	International Space Station
IV	Intravehicular
IVA	Intravehicular Activity
JSC	Johnson Space Center
LCD	Liquid Crystal Display
LCVG	Liquid Cooling and Ventilation Garment
LED	Light Emitting Diode
LMRV	Low Mode Relief Valve
LSS	Life Support Subsystem
LTA	Lower Torso Assembly
MAG	Maximum Absorbency Garment
MCC	Mission Control Center
Metox	Metal Oxide
MMU	Manned Maneuvering Unit
MOD	Mission Operations Directorate
MWC	Multiple Water Connector
MWS	Mini-Workstation
NiMH	Nickel Metal Hydride
nm	nanometer
NSI	NASA Standard Initiator
NVRAM	Non-Volatile RAM
OBS	Operational Bioinstrumentation System
ORU	On-Orbit Replaceable Unit
PTT	Push-To-Talk
QD	Quick Disconnect
PCB	Printed Circuit Board
PLSS	Primary Life Support Subsystem
PPRV	Positive Pressure Relief Valve
PSA	Power Supply Assembly
RAM	Random Access Memory
RF	Radio Frequency
ROT	Rotational
ROM	Read-Only Memory
RTDS	Real-Time Data System
RTV	Room-Temperature Vulcanizer
SAFER	Simplified Aid for EVA Rescue
SCOF	SOP Checkout Fixture
SCU	Service and Cooling Umbilical

SEMU	Short EMU
SOP	Secondary Oxygen Pack
SSA	Space Suit Assembly
SSAPH	SSA Power Harness
SSCS	Space-to-Space Communication System
SSER	Space-to-Space EMU Radio
SSOR	Space-to-Space Orbiter Radio
SSSH	Space Shuttle Systems Handbook
SSSR	Space-to-Space Station Radio
TCU	Thermal Comfort Undergarment
TCV	Temperature Control Valve
TMG	Thermal Micrometeoroid Garment
TRAN	Translational
UCD	Urine Collection Device
UHF	Ultrahigh Frequency
VDA	Valve Driver Assembly
VOX	Voice-Operated Transmission
VRAM	Volatile Random Access Memory
WP	Water Pressure